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Aggregate Resources Inventory of Haldimand and Alnwick Townships Northumberland County

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Aggregate Resources Inventory
Paper 143

By Staff of the Sedimentary and Environmental Geoscience
Section, Ontario Geological Survey

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Abstract

This report includes both an inventory and evaluation of sand and gravel, as well as bedrock resources, in Haldimand and Alnwick townships in Northumberland County. This report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Aggregate Resources Act.

Thirty-two deposits have been grouped into 7 primary Selected Sand and Gravel Resource Areas. These Resource Areas consist of eskers, subaqueous fans, a subaqueous fan-glaciolacustrine beach and an ice-contact stratified drift deposit. These Resource Areas occupy an available area of 420 ha containing potential sand and gravel resources of approximately 62 million tonnes. These primary resource areas are generally capable of supplying a wide range of aggregate products, including Granular A and hot-laid stone. Ten deposits consisting of eskers, esker segments, subaqueous fans and glaciolacustrine beaches have been designated as resource areas of secondary significance. These deposits are not considered to be as significant as the Selected Sand and Gravel Resource Areas but they

do add significantly to the townships' resource base. The remaining deposits in the townships are designated at a tertiary level of significance. Some of these tertiary deposits may have the potential to produce locally significant amounts of good quality aggregate.

Thick drift covers most of the Paleozoic bedrock of the Verulam and Lindsay formations in Haldimand and Alnwick townships. Areas where the Lindsay Formation is overlain by less than 8 m of drift have been selected as Bedrock Resource Area 1. Limestone from this formation may be suitable for cement production and has been excavated for crushed stone in southeastern Ontario. An estimated 660 ha are currently available for extraction in these selected deposits, containing possible resources of 314 million tonnes.

Selected Resource areas are not meant to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extraction development and/or resource protection.

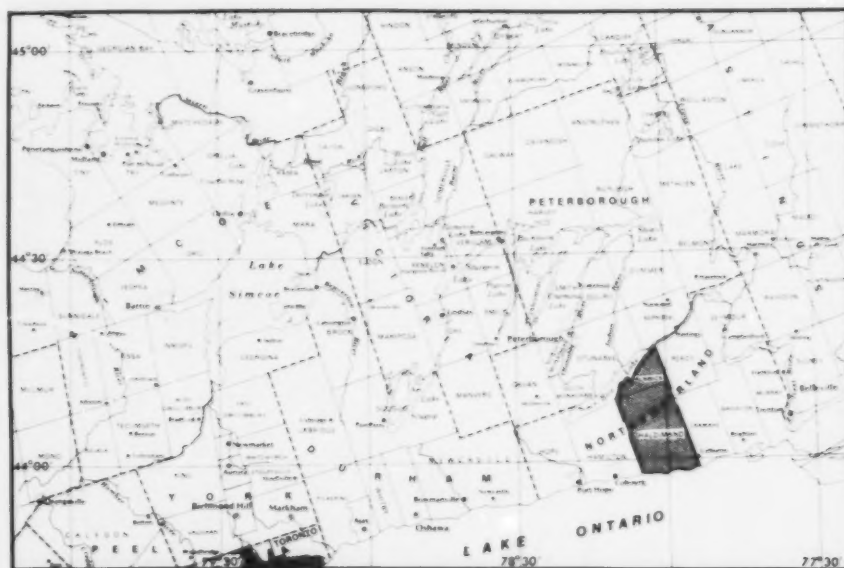


Figure 1. Key map showing the location of Haldimand and Alnwick townships, Northumberland County, scale 1:1 800 000.

Résumé

Ce rapport comprend à la fois un inventaire et une estimation des ressources en sable et en gravier, ainsi que des ressources du substratum rocheux des cantons de Haldimand et d'Alnwick. Il fait partie du programme sur l'Inventaire des ressources en agrégat pour les secteurs régis par la Loi sur les ressources en agrégat.

On a regroupé trente-deux gisements en sept (7) zones ressources de sable et de gravier d'une importance primordiale. Ces zones ressources contiennent des eskers, des cônes de dejection subaquatique, un dépôt de cône de dejection subaquatique glaciolacustre de plage et un dépôt du drift de contact glaciaire stratifié. Les zones ressources occupent une superficie disponible de 425 hectares et contiennent des ressources potentielles en sable et en gravier d'environ 64 millions de tonnes. La plupart de ces zones ressources primaires pourraient fournir un grand nombre de produits d'agrégats, dont le granulé A et le gravier utilisée pour l'asphalte répandu à chaud. Comme zones d'importance secondaire, on a identifié dix gisements, qui comprennent des eskers, des segments d'eskers, des dépôts de cônes de dejection subaquatique et des dépôts glaciolacustres de plage. Sans être aussi importants que les zones ressources choisies de sable et de gravier, ces gisements augmentent considérablement les ressources potentielles des cantons. Les autres gisements des cantons se situent à un niveau d'importance tertiaire. Quelques-uns de ces gisements tertiaires pourraient éventuellement produire des agrégats de haute qualité en quantités importantes.

Dans les cantons de Haldimand et d'Alnwick, une couche de drift recouvre la plus grande partie du socle paléozoïque des formations de Verulam et de Lindsay. Les zones où la formation de Lindsay est recouverte d'une couche de drift inférieure huit (8) mètres d'épaisseur ont été choisies comme constituant la zone ressource 1 du socle. Le calcaire de cette formation convient à la production de ciment et il a été exploité comme la pierre concassée dans le sud est de l'Ontario. On dispose actuellement d'une superficie d'à peu près 500 hectares de ces gisements choisis, ce qui permettrait d'exploiter une ressource possible de 200 millions de tonnes.

Les zones sélectionnées pour leurs ressources ne sont pas destinées à être réservées à un seul usage permanent. Elles représentent des zones où une ressource importante a été reconnue et peut être réservée en totalité ou en partie pour l'exploitation et/ou en tant que réserves de ressources.

Cette publication est disponible en anglais seulement.

Aggregate Resources Inventory of Haldimand and Alnwick Townships Northumberland County

By Staff¹ of the Sedimentary and Environmental Geoscience Section

1. Project Supervisor: C. Baker; field work and report by M. McCrae and G. Gorrell; compilation and drafting by Staff of the Sedimentary and Environmental Geoscience Section. Assistance with review provided by the Resident Geologist, Ministry of Northern Development and Mines, Tweed, Ontario and the Mineral Resources Staff, Lindsay District Office, Ministry of Natural Resources.

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Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1987, the total tonnage of mineral aggregates extracted was 142 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1989).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use

of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of the resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential for bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey and by Regional and District offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 11 to 45 kg units from existing pit faces or from test pits. The samples are analyzed for grain size distribution and in some cases absorption, Los Angeles abrasion and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Ontario Ministry of Transportation or in the Geoscience Laboratory, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size and depth of extraction of pits licenced under the Aggregate Resources Act are obtained from records held by Regional and District offices of the Ontario Ministry of Natural Resources. The co-operation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material.

These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000. These base maps are prepared by the Land and Resource Information Branch, Ontario Ministry of Natural Resources with information taken from maps of the National Topographic System by permission of Energy, Mines and Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in hectares. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 17 700 (the density factor). This factor is approximately the number of tonnes in a 1 m thick layer of sand and gravel, 1 ha in extent, assuming an average density of 1770 kg/m³.

$$\text{Tonnage} = \text{Area} \times \text{Thickness} \times \text{Density Factor}$$

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e., original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of hectares unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g., wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 17 700) to give an estimate of the sand and gravel tonnage (Column 7) presently

available for extractive development and/or resource protection.

Resource estimates are calculated for deposits of primary significance. Resource estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 15 m of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 18 m is used for thickness. Volume estimates are then

multiplied by the density factor (the estimated weight in tonnes of a 1 m thick section of rock, 1 ha in extent).

Resources of dolostone are calculated using a density factor of 2649 kg/m³, sandstone resources are calculated using a density estimate of 2344 kg/m³ and shale resources are calculated with a factor of 2408 kg/m³.

UNITS AND DEFINITIONS

The measurements and other primary data available for resource tonnage calculations are given in Metric units in the text and on the tables which accompany the report. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (*see* Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Two maps, each portraying a different aspect of the aggregate resources in the townships, accompany the report. Map 1, "Sand and Gravel Resources", gives a comprehensive inventory and evaluation of the sand and gravel resources in the report area. Map 2, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments and identifies the Selected Bedrock Resource Areas.

MAP 1: SAND AND GRAVEL RESOURCES

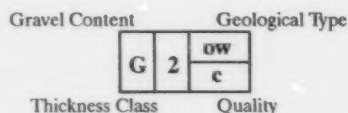
Map 1 shows the extent and quality of sand and gravel deposits within the study area and evaluation of the aggregate resources. The map is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete.

The present level of extractive activity is also indicated on Map 1. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicensed pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type) and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 3 to 6 m thick containing more than 35% gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit. "G" indicates that the deposit contains more than 35% gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30% gravel, 60% sand and 10% silt and clay:



Selected Sand and Gravel Resource Areas

All the Selected Sand and Gravel Resource Areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark red shading on Map 1.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units. They represent areas in which a major resource is known to exist, and may be reserved wholly or partially for extractive development and/or resource protection.

Deposits of secondary significance are indicated by medium red shading on Map 1. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered part of the aggregate supply of the area.

Areas of tertiary significance are indicated by light red shading. They are not considered to be important resource areas because of their low available resources or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall resources in the rest of the project area. Generally, deposits in Class 1 (greater than 6 m thick) and containing more than 35% gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in areas with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S), fines (C), oversize (O) and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35% gravel in addition to a minimum of 20% material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10% may impede drainage in road subbase aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20% oversize material (greater than 10 cm in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O" or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Sedimentary and Environmental Geoscience Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendixes B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular A and Granular B Type I; Hot-Laid Asphaltic Sand Nos.

1,2,3,4 and 8, and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding the project area should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, townships that have large resources in comparison to their surrounding region, constitute a regionally significant resource area. Townships with high resources in

proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 2: BEDROCK RESOURCES

Map 2 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum and Aggregate Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 2 is based on concepts similar to those outlined for Map 1.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 1 m of drift, areas of 1 to 8 m of drift, and areas of 8 to 15 m of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 1 m of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 8 m thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 8 to 15 m of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 15 m of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 2 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, licenced acreage and an estimate of face height. Unlicensed quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 2 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in metres beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in metres beside it. The test holes may be further described in Table 7.

Selection Criteria

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria

and regional considerations are identical to those for sand and gravel deposits.

Selected Resource Areas

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 2 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 2 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Part III — Assessment of Aggregate Resources of Haldimand and Alnwick Townships

LOCATION AND POPULATION

Haldimand and Alnwick townships are 39 554 ha in size and are located in the southeastern part of Northumberland County in southeastern Ontario. The townships are shown on the Rice Lake (31 D/1), Trenton (31 C/4), Port Hope (30 M/16), Presqu'île (30 N/13) and Peterborough (31 D/8) map sheets of the National Topographic System, at a scale of 1:50 000.

The population of Haldimand and Alnwick townships was 5036 in 1991 (Ontario Ministry of Municipal Affairs 1992). This represents an increase of 20.8% since 1982 (Ontario Ministry of Municipal Affairs and Housing 1983). The majority of the people residing in these townships live in rural areas. Well-drained, sandy soils are present over much of the area, especially in the vicinity of the Oak Ridges moraine. This predominance of sandy material has promoted the development of forest agriculture.

Communities within Haldimand Township include Brookside, Burnley, Carmel, Centreton, Eddystone, Fenella, Grafton, Lakeport, Oak Heights, Vernonville and Wicklow. Communities within Alnwick Township include Alderville, Dunnette Landing, Robin Landing and Roseneath.

Major road access within both townships is provided by King's Highway 45 which links the town of Cobourg, in Hamilton Township, with the village of Norwood, located about 10 km northeast of Rice Lake, in Asphodel Township. King's highways 401 and 2 permit east and west travel across the southern portion of Haldimand Township. In addition to these major roads, there is the irregular network of paved and gravel-surfaced county and township roads which provide access to the interiors of both townships.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Haldimand and Alnwick townships are characterized by a wide variety of glacial landforms and deposits. The features that are present include eskers, subaqueous fans, glaciolacustrine beaches, glaciolacustrine deltas, glaciolacustrine plains and the moraine. The distribution of the surficial granular materials (Map 1) is the result of both glacial erosion and deposition, as well as meltwater and shoreline processes that occurred during the Late Wisconsinan Substage of the Pleistocene Epoch (also known informally as the "Great Ice Age"). The Late Wisconsinan lasted from approximately 23 000 to 10 000 years ago, during which time the mar-

ginal lobes of the Laurentide Ice Sheet repeatedly advanced and melted.

During Late Wisconsinan time, the project area was covered by the southwestward advancing Simcoe lobe. At the same time, the Ontario lobe likely occupied a position closely approximating that of the present-day Lake Ontario basin. These glacial lobes were responsible for depositing glacial drift that increases in thickness towards the Oak Ridges moraine.

Haldimand and Alnwick townships fall within 4 physiographic regions which run parallel to the Lake Ontario shoreline. These regions are: Peterborough drumlin field, Oak Ridges moraine, South slope and Iroquois plain (Chapman and Putnam 1984).

Part of the Peterborough drumlin field occurs north of the Oak Ridges moraine in Alnwick Township. Some of the drumlins in this area are larger than the majority of drumlins in the rest of the field.

The Oak Ridges moraine was first identified by Taylor (1913). The moraine is the dominant landform in the region reaching, on average, 300 m in elevation along its ridge crest and a maximum height of 360 m in Haldimand Township. Drilling and field mapping of the moraine indicate that a predominance of fine-grained sediments comprise the surficial material of this feature. The uppermost 45 to 60 m is commonly composed of sand, silt and clay.

There is general agreement "that the Oak Ridges moraine was formed between two ice lobes" (Gravenor 1957), one lobe being the Ontario lobe and the other being the Simcoe lobe. As the ice retreated, an opening was created between the lobes which acted as a focus for meltwater flow and, thus, sediment deposition. Hence, the name established by Gravenor "Oak Ridges interlobate kame moraine".

South of the Oak Ridges moraine is the South slope. This slope is covered by drumlins consisting of highly calcareous till. The till generally contains a high fines content making it unsuitable for use as aggregate. Also occurring in this region are eskers and esker-subaqueous fan complexes of considerable size. The sand and gravel of these features was deposited within conduits (rivers) draining beneath the ice. These deposits are excellent sources of crushable gravel and finer grades of material.

Some of the southwest-trending drumlins in the area have small, coarse gravel deposits associated with their southwestern sides (known as ice-contact lee-side cavity fills). These deposits are usually small in size and tend to contain oversize material, thus they are generally useful only for local extraction.

As the Ontario lobe slowly retreated from this region (approximately 10 000 years ago), large volumes of meltwater accumulated in the Ontario basin forming glacial Lake Iroquois. On the Iroquois plain, beach deposits of glacial Lake Iroquois appear as subtle, continuous ridges that occur in the vicinity of King's Highway 401. Most of these beach deposits are of limited size, as they are both narrow and quite thin, seldom exceeding 3 m in thickness. Many of these deposits have either been exploited for their aggregate or sterilized by the location of King's Highway 401. To the south of the highway, there is a belt of drumlins with silt deposits in the low-lying areas. Along the Lake Ontario shoreline, there is a thin drift of sand, fine sand and silt.

EXTRACTIVE ACTIVITY

One hundred and twenty sand and gravel pits have been identified in Haldimand and Alnwick townships. The majority of these have been developed in subaqueous fans, eskers, glaciolacustrine beaches, small ice-contact deposits and the Oak Ridges moraine. At the time of writing, 12 of these pits were licenced to operate. The licenced properties occupy a total area of 342.69 ha. The average annual production over the twelve-year period from 1980 to 1991 for Haldimand and Alnwick townships was approximately 216 000 tonnes and 60 000 tonnes, respectively. Most of the unlicensed pits have been abandoned and are overgrown.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular materials. These deposits occupy a total of approximately 9100 ha and contain an original resource tonnage of 960 million tonnes. Many of these deposits have good potential for extraction due to the large quantity and good quality of the aggregate. However, only the deposits considered to be potential sources of high quality aggregate are suggested for protection.

The deposits selected at the primary level of significance have been grouped into 7 Selected Sand and Gravel Resource Areas. These deposits contain aggregate resources considered potentially suitable for the production of a wide variety of aggregate. In addition, several deposits have been selected at the secondary level. These deposits contain a large proportion of sand considered potentially suitable for the production of granular subbase but they may yield some quantities of coarse granular material as well.

The Selected Sand and Gravel Resource Areas of primary significance occupy a total of about 480 ha. Cultural constraints and previous extraction reduce the estimated area currently available to about 420 ha. These areas contain possible sand and gravel resources of 62 million tonnes.

Selected Sand and Gravel Resource Area 1

Two deposits situated northeast of Wicklow in Haldimand Township are included in Sand and Gravel Resource Area 1. The northernmost deposit has been designated as Area 1a. One licenced pit (no. 1) is currently operating in this deposit. Faces in pit no. 1 contain sediments characteristic of two different depositional environments: the upper 1 to 2 m is well-washed, horizontally stratified, coarse sand and gravel, indicative of a glaciolacustrine beach; the lower 5 to 6 m is medium to coarse sand with isolated pockets of cobble gravel, typical of a subaqueous fan. Aggregate in the pit appears best suited for the production of pit-run material. Ministry of Transportation (MTO) information indicated crushable gravel was available with selective extraction. Some oversize material, present in the lower portion of the pit, may require removal or crushing. In some areas the deposit is poorly graded and there is an excess of fines. Two test holes (HD-TH-1 and -2) drilled through the pit floor indicate that fine to coarse gravel and sand are present for an additional 15 m, approximately. However, the water table was encountered approximately 4 m beneath the pit floor. This deposit likely reaches the greatest probable thickness to the west of the pit, as the surface of the drumlin underlying this deposit also slopes westward. MTO data from 3 test holes, excavated in the western part of the deposit, indicate the presence of at least 3 m of crushable gravel.

The subsurface information for Area 1b is obtained from a series of MTO test holes excavated in this site. The test holes which are approximately 5 m deep, revealed layers of gravel 1 to 4 m thick. The sand and gravel appears suitable for a wide variety of aggregate products from Granular A to hot-laid sand. Till may be encountered at depths of more than 6 m but the deposit appears to thicken to the east.

Resource Area 1 occupies 34 ha of which 26 ha are currently available for extraction. Assuming an average thickness of 15 m for Area 1a and 10 m for Area 1b, aggregate resources are estimated to total 6 million tonnes. The area is readily accessible via township roads.

Selected Sand and Gravel Resource Area 2

Eskers and subaqueous fans are included within Selected Sand and Gravel Resource Area 2. The esker deposits have been designated as Areas 2a and 2c to 2g. The subaqueous fan deposits have been designated as Areas 2b and 2h.

Area 2a constitutes the largest esker in the area, reaching nearly 12 m in height. A test pit excavated into the esker crest revealed 3.8 m of clean, coarse to cobble gravel (HD-TH-15). Two samples from this test hole contained 75 to 82% gravel. This gravel appears suit-

able for granular base (Figure 4a). Similar material is expected to be present throughout the remainder of this deposit. This area is a potential source of coarse crushable gravel.

The large subaqueous fan outlined as Area 2b is associated with and surrounds the Area 2a esker. This fan deposit is expected to contain sediments that exhibit a wide grain size distribution. The deposit may coarsen with depth. The coarsest material will likely occur in closest proximity to the esker. The results from test pit HD-TH-08 and drill hole HD-TH-09 revealed that coarse crushable gravel, suitable for granular base, occurred within 4 to 10 m of surface near the southern edge of the deposit (Figure 3a, HD-TH-8). Test hole HD-TH-7 did not reveal any coarse gravel within 6 m of the surface, however, this may be due to the variable nature of the deposit. Coarser material may be available at depth.

Two eskers comprise Resource Areas 2c and 2d. A portion of Area 2c was previously extracted from a way-side pit that is now overgrown. MTO data from pit no. 33 indicated that this aggregate met the standards for a wide variety of aggregate products but some oversize material had to be removed or crushed. Blending would have been required to produce hot-laid asphalt sand. Recent drilling (HD-TH-17 and -18) within Area 2c revealed that a substantial quantity of coarse and cobble gravel is located within 10 m of the surface. A sample from HD-TH-17 indicates that the material is suitable for crushing (Figure 5a). MTO test holes to the east of pit no. 33 revealed gravel layers up to 5 m thick, however, the percentage of crushable gravel may be too low for high-specification aggregate products.

The Area 2d esker, as with Area 2a, appears to contain a considerable amount of coarse gravel suitable for Granular A. Several drill holes indicate that this deposit is primarily composed of alternating layers of coarse to cobble gravel and coarse sand. Refusals at depths of 5 and 10 m in drill holes HD-TH-19, -20 and -21, suggest that this esker may be cored with large boulders. The water table was intersected at a depth of 4.6 m in the northern part of the deposit (HD-TH-22).

Resource Areas 2e and 2f are smaller esker segments which are extensions of the southern deposits. Therefore, it is probable that these landforms contain aggregate materials of similar grain size and physical properties as those previously described for Resource Area 2d.

Resource Area 2g is an esker that measures approximately 5 to 6 m in height. Backhoe excavation into the side of the esker (HD-TH-26) revealed 3.8 m of fine to coarse gravel with fine to coarse sand layers. A sample of this aggregate is suitable for crushing (Figure 6a). A drill hole located on the lower flank of this deposit (HD-TH-24) revealed 10 m of coarse gravel layers (up to 3 m thick) alternating with layers of generally medium sand (less than 2 m thick). A backhoe excavation in the same area (HD-TH-25) revealed 3.1 m of cobble gravel overlain by 0.6 m of fine sand. A sample of the

gravel from this test pit met MTO specifications for granular base (Figure 6a). Several MTO test holes in the western end of the deposit also revealed 2 to 4 m of gravel overlain by up to 2 m of sand. The percentage of crushable gravel is variable, therefore, selective extraction may be necessary. Oversize material may have to be removed or crushed.

Resource Area 2h is a subaqueous fan that completely encompasses the Area 2g esker mentioned above. Subsurface information for this deposit is from two drill holes (HD-TH-23 and -27) which revealed coarse gravel layers within 10 m of the surface. A blanket of fine-grained sediments was encountered in test hole HD-TH-23. The material in this deposit is variable and subsurface investigation is recommended prior to extraction.

In Resource Area 2, 165 ha are available for extraction. Based on a range of thicknesses from 5 to 18 m, potential aggregate resources total 23 million tonnes. Access to parts of this area is by township roads.

Selected Sand and Gravel Resource Area 3

Two subaqueous fan deposits form Selected Sand and Gravel Resource Area 3. A narrow veneer of fine sediment separates these deposits at surface.

Pit no. 4 has been developed in the subaqueous fan deposit that constitutes Area 3a. The north face of the pit exposed approximately 3 to 5 m of fine sand to silt over 4 to 5 m of fine to coarse sand and gravel. Due to the variable textural distribution of the sediments, this pit typically yields pit-run material. In some areas, the pit is contaminated by layers of sandy clay till between 1 and 2 m thick. Two drill holes (HD-TH-40 and -41) penetrating the pit floor revealed that the aggregate is limited to a depth of approximately 1.5 m before till is encountered. Extensive stripping has been required in some areas of this pit to remove the fine sediments covering the gravel. Within Area 3a, gravel is expected to occur near the surface and under varying depths of fine aggregate. This fine aggregate mantle is expected to increase towards the northeast. Test hole HD-TH-49 in the northern limits of the deposit revealed approximately 5 m of fine aggregate overlying gravel.

Area 3b is also a subaqueous fan deposit. Detailed drill investigation of this area indicates that the distribution of aggregate is quite variable. In the southern part of the deposit, test holes HD-TH-35 and HD-TH-36 revealed 2 to 3 m of aggregate overlying sandy till. Whereas further to the north, 3 test holes (HD-TH-43, -45 and -47) revealed alternating layers of sand and gravel. Refusals incurred in test holes HD-TH-45 and -47 at depths of 7.1 m and 11.6 m, respectively, suggest that boulder gravel is also present at depth. In addition, two backhoe test pits (HD-TH-44 and -46), approximately 4 m deep, exposed sediments ranging from fine sand to coarse gravel. Samples of the gravel from these two test pits contained between 40

and 60% gravel, 58 and 38% sand and 2% fines. Only one sample was unsuitable for crushing (Figure 7a). A wide variety of materials could be produced from this area with selective extraction and sand control measures in place.

Resource Area 3 covers 28 ha, however, only 16 ha are available for extraction. Aggregate resources of 2 million tonnes are available assuming average deposit thicknesses of 10 and 18 m. The area is readily accessible by township roads.

Selected Sand and Gravel Resource Area 4

An esker and subaqueous fan complex located on the northeastern flank of the Oak Ridges moraine has been selected as Area 4. Several small eskers, generally less than 5 m in height, are located in this resource area. A test hole (HD-TH-56) in one of these small eskers revealed 3.8 m of clean, fine to coarse gravel suitable for crushing (Figure 8a). Abandoned pit no. 54 is present in another esker, its 6 to 8 m faces revealed coarse gravel with pockets of sandy gravel.

Resource Area 4 is readily accessible via township roads, one of which intersects the resource area. It occupies 7 ha of which 4 ha are available for extraction. Assuming a deposit thickness of 10 m, sand and gravel resources are estimated to be less than 1 million tonnes.

Selected Sand and Gravel Resource Area 5

A multitude of large, elongated, coarse gravel hills of ice-contact origin comprise Selected Sand and Gravel Resource Area 5. Drill and backhoe testing of these large deposits, some reaching up to 10 m in height, revealed a variety of sediments, predominantly clean, fine to coarse gravel with medium to coarse sand layers. Four gravel samples taken from test holes HD-TH-65 and -67 were suitable for crushing and contained only 1 to 3% fines (Figures 8a and 9a). Lenses of silt to silty sand, encountered in several test holes (HD-TH-61, -62, -64 and -68), should be avoided during extraction.

Pit no. 7 is located on a ridge at the northern flank of the Oak Ridges moraine. At this location the gravel hills have become more subdued and the aggregate occurs as a veneer that varies from 2 to 3 m in thickness. This aggregate veneer blankets the irregular surface of the underlying fine sediment. This relationship is reflected by the various levels of the pit floor. The 3 to 4 m high faces of pit no. 7 contained fine to coarse sand and gravel, which in places, hosted pockets of cobble to boulder gravel. Aggregate from this location is suitable for crushing. Blending would be required for some hot-laid products.

Resource Area 5 occupies 105 ha of which 96 ha are available for extraction. The average deposit thickness ranges from 5 to 20 m resulting in 16 million tonnes of

available aggregate. This area is in close proximity to King's Highway 45 as well as numerous township roads.

Selected Sand and Gravel Resource Area 6

A complex of eskers and subaqueous fans located near the southwestern border of Haldimand Township are included within Selected Sand and Gravel Resource Area 6.

The largest deposit, identified as Area 6a, contains sinuous esker-like sand and gravel ridges that appear to gradually change into subaqueous fans. The esker-like portions occur to the west side of this deposit and the subaqueous portions occur to the east. This apparent orientation suggests that this deposit will coarsen from east to west. Drill and backhoe investigations of the eastern portion of this deposit (HD-TH-77 and -78) revealed that the upper 1.5 m is composed of coarse gravel. A sample of the aggregate from HD-TH-78 appears borderline for crushing (Figure 10a). The underlying clean, medium sand may also provide low-specification sand products. The unusual character of this deposit warrants detailed subsurface investigations before any extractive activity is undertaken.

Area 6b is an esker measuring about 4 to 5 m in height. Road cuts through this feature display a predominance of clean coarse sand. The few layers of fine to coarse gravel less than 0.5 m thick would be suitable as granular subbase. Due to the variable distribution of granular materials in eskers, it is possible that this deposit may also contain high concentrations of coarse aggregate.

Area 6c is interpreted as a small subaqueous fan. Silty fine sand and gravel were found within 1 m of the surface of this undeveloped deposit. The deposit is expected to contain material similar to that found in the subaqueous part of Resource Area 6a.

Resource Area 6 has 77 ha available for extraction. Six million tonnes of sand and gravel are available assuming that the average deposit thickness is 5 m. Access to this area is provided by numerous township roads branching off of King's Highway 45.

Selected Sand and Gravel Resource Area 7

One large esker approximately 10 m in height and situated close to the southern shore of Rice Lake constitutes Area 7. Four abandoned pits (nos. 107 to 110) in the area revealed 2 to 8 m of fine to coarse gravel with fine to medium sand. With selective extraction, a wide variety of crushed products are potentially available from this area. Selective extraction is also recommended to avoid areas of high fines content. The close proximity to the lake and high concentrations of residents and roads on and near this deposit may be obstacles to extraction.

Approximately 34 ha are available for extraction in Resource Area 7. Assuming a deposit thickness of 15 m,

approximately 9 million tonnes of sand and gravel are present. Access to the area is provided by township roads which intersect the resource area in numerous places.

Resource Areas of Secondary Significance

Ten deposits within Haldimand and Alnwick townships have been selected at the secondary level of significance. A predominance of sand comprises the bulk of the material in these deposits. There are, however, localized areas of gravelly, medium to coarse sand suitable for use as road subbase. Some of the smaller deposits may also contain coarse material suitable for crushing.

Of the deposits selected at the secondary level, four are subaqueous fans of large areal extent. Four test holes (HD-TH-3 to -6) were excavated in the subaqueous fan associated with Selected Sand and Gravel Resource Area 1. Gravel layers were observed in all the test holes and samples of gravel from HD-TH-4 and -6 appear borderline for crushing (Figure 2a). Layers of silt and clay were also observed, these layers should be avoided during excavation. The water table may be encountered near the surface in some areas of this deposit.

The extensive subaqueous fan deposit associated with Selected Sand and Gravel Resource Area 2 is expected to be a good source of pit-run aggregate with pockets of crushable gravel. Gravel layers were encountered within 4 m of the surface in two test holes (HD-TH-28 and -29), however, fine sand to clay layers were also encountered to depths of 10 m. Medium sand was encountered in test hole HD-TH-30, to a depth of 13.7 m. Further subsurface investigation is recommended prior to development and selective extraction would be necessary to produce high-specification aggregate.

Surrounding Selected Sand and Gravel Resource Area 4, is a subaqueous fan deposit. This deposit appears to contain highly variable material. A house foundation site revealed 2 m of interstratified medium to coarse sand and fine gravel. Test hole HD-TH-53 revealed approximately 9 m of medium sand and fine gravel over 9 m of medium sand and coarse gravel. Fine sand was the only material exposed in the 9 m test hole HD-TH-55. Sand is at surface over most of the deposit, however, gravel layers may occur at varying depths. A sample from HD-TH-54 revealed that the gravel is suitable for crushing (Figure 8a). Subsurface investigation is suggested prior to extraction.

The fourth subaqueous fan—ice-contact deposit is located west of Fenella. Very little subsurface information is available for this deposit. Sand and gravel were found at the surface in some areas of the deposit. Pit no. 6 in the southern part of the deposit is presently overgrown, however, MTO records show the material

was suitable for pit-run aggregate. Test holes excavated in the pit uncovered pockets of gravel, some of which was suitable for crushing. Pit no. 73, to the north of pit no. 6, was partially overgrown but the faces revealed 5 to 6 m of fine gravelly sand. The undeveloped part of this deposit may contain pockets of gravel similar to the gravel hills in Selected Sand and Gravel Resource Area 5. These hills may be covered by varying thicknesses of finer aggregate. Subsurface investigation is recommended prior to extraction.

Four esker and esker segment deposits occurring northeast of the moraine have also been selected at the secondary level. The southernmost deposit contains 3 abandoned pits (pit nos. 59, 60 and 61) with face heights of 2 to 3 m. Sand and gravel are exposed, however, the best material in two of the pits appears to be in the floor of the pit. Pit nos. 100 and 101 were opened in the next selected esker segment to the north in Alnwick Township. The 3 to 4 m faces of pit no. 100 revealed 2 to 3 m layers of fine to coarse gravel interbedded with coarse sand. Pit no. 101 in the eastern end of the deposit revealed very different material. The 1 to 3 m faces revealed fine sand with less than 5% gravel. Sand was also exposed on the surface of an 8 to 10 m slope near this pit. This deposit contains highly variable material. The northernmost deposit contains pit no. 103. The pit faces and several MTO test holes revealed gravel with sand layers. A rehabilitated pit in the same esker system in neighbouring Percy Township was capable of supplying Granular A and hot-laid stone and sand. The centrally located, undeveloped, selected esker revealed gravelly fine sand within 1 m of the surface. This deposit is expected to contain material similar to the other eskers, however, subsurface investigation is recommended prior to extraction.

Two glaciolacustrine beach deposits in southeastern Haldimand Township have been selected at the secondary level of significance. Subsurface information from test holes excavated by MTO in the central part of the northern deposit indicate gravel layers 1 to 3 m thick. Crushable gravel would be available only with selective extraction but sand quality is good. Coarse aggregate may be concentrated in the north-central arm of the northern deposit.

Resource Areas of Tertiary Significance

The vast majority of the deposits identified within Haldimand and Alnwick townships have been classified at the tertiary level of significance. The Oak Ridges moraine appears to only be a source of fine sediment. In many instances, the various glaciolacustrine beach, ice-contact, esker, subaqueous fan and lee-side cavity fill deposits may contain potentially viable aggregate deposits. Those deposits with the gravel designation have been interpreted as the most likely sources for granular aggregate. The usually small size of these tertiary gravel deposits and the highly variable grain

size distributions within them, may result in only limited yields of quality granular material.

BEDROCK GEOLOGY AND RESOURCE POTENTIAL

Previous mapping of the area by Liberty (1960) and Carson (1980a, 1980b) indicates that the bedrock underlying the surficial material in the report area consists of formations that are Middle to Late Ordovician in age. Of the four formations of the Simcoe Group (Liberty 1969) only the upper two, the Verulam Formation and the Lindsay Formation, are present.

The older bedrock unit, the Verulam Formation, underlies all of Alnwick Township and part of northern Haldimand Township. This formation consists of pure to argillaceous limestone with interbedded shale (Carson 1980a, 1980b). The limestone varies in colour from medium to dark brown to grey. It is usually medium to coarse grained, however, beds of subliothographic to fine-grained limestone are also present but not abundant. Individual beds range from 4 to 10 cm thick and are commonly interbedded with shale and shaly limestone up to 6 cm thick. Rock from this formation has been used for crushing and cement manufacturing elsewhere in eastern Ontario. The Verulam Formation has not been selected for resource protection in the report area because of the generally thick drift cover over most of this formation.

The overlying, younger, Lindsay Formation forms the bedrock of the remainder of Haldimand Township. This formation consists of two members, an upper, black calcareous shale member, referred to as the Collingwood Member, and a lower unnamed nodular limestone member (Russell and Telford 1983). Only the lower member is present in the report area. This lower member consists of light to medium grey, subliothographic to fine-grained, nodular limestone which occurs in beds 20 to 30 cm thick (Carson 1980a, 1980b). The formation outcrops only along the Lake Ontario shoreline in the vicinity of Chub Point, about 3 km southeast of Grafton. Water well data indicate that, with the exception of areas along the Lake Ontario shoreline, the overburden thickness is generally greater than 20 m throughout the rest of the township. The Lindsay Formation limestone is suitable as crushed stone and for use as a raw material in the manufacture of cement, for this reason, areas overlain by less than 8 m of drift have been selected for possible resource protection.

Selected Bedrock Resource Area 1

Selected Bedrock Resource Area 1 consists of areas of the Lindsay Formation that are overlain by less than 8 m of drift. No quarries have been developed in this area. A significant thickness of Lindsay Formation limestone may be available for quarrying, as exposures of approximately 37 m in height occur in the Ogden Point Quarry

in neighbouring Cramahe Township (Derry Michener Booth and Wahl and Ontario Geological Survey 1989). The rock from this quarry is used for the production of cement. Granular base and subbase have also been produced from the Lindsay Formation elsewhere in southeastern Ontario. The utilization of the Lindsay Formation limestone in neighbouring townships and the fairly uniform lithological character of the rock indicate the economic potential of the Lindsay Formation. Extensive testing of the rock should, however, be undertaken prior to the development of any site.

Selected Bedrock Resource Area 1 covers approximately 840 ha of which 660 ha are considered available for extraction. Assuming a workable thickness of 18 m, bedrock resources are estimated to be 314 million tonnes. Access to this area is provided by King's Highway 2 and Lake Ontario.

AGGREGATE QUALITY AND SUITABILITY

During field investigations, 22 samples were taken from backhoe test pits. The samples were analyzed for grain size distribution (Figures 2a to 10b) and 6 aggregate quality tests were performed. These tests included absorption, Magnesium Sulphate Soundness, Los Angeles Abrasion, Mortar Bar Accelerated Expansion (performed on a select few) and Micro Deval Abrasion tests, as well as petrographic analysis. The results of these tests are portrayed in Table 9. The grain size analyses and the quality tests were all performed in the laboratories of the Ministry of Transportation, Downsview.

Almost all of the 22 gravel samples are suitable for crushing thus for the production of high-specification aggregates. Results from the Magnesium Sulphate Soundness, Los Angeles Abrasion, Mortar Bar Accelerated Expansion and absorption tests were all acceptable for coarse aggregate. The petrographic numbers for all of the samples are acceptable for use in granular base.

Quality tests show the aggregate is generally suitable for most hot-laid products, however, some of the samples graded too fine. High concrete petrographic numbers may limit the use of some aggregate for concrete.

There is a good supply of high-specification aggregates in Haldimand and Alnwick townships. Selective extraction of the crushable gravel may be necessary to produce the high-specification aggregate products.

SUMMARY

The sand and gravel deposits in the report area are the products of glacial and meltwater activities that occurred during the Late Wisconsinan Substage of the Pleistocene Epoch. Some of these deposits, containing significant resources of sand and gravel, have been designated into 7 primary resource areas. Numerous deposits of secondary significance, which add consider-

ably to the project area's resource base, have also been selected. Many of the tertiary deposits may contain concentrations of aggregate and may yield limited quantities of quality granular material. Therefore, care should be taken to ensure the maximum availability of as much and as many of the resource areas as possible.

In general, the report area contains abundant resources of high-specification aggregates. Those deposits selected at the primary level contain most of the report area's potential resources of crushable gravel. The secondary deposits are primarily sources of sand suitable for use as low-grade aggregate.

Haldimand and Alnwick townships are underlain by Middle to Upper Ordovician limestones and shales of the Verulam Formation and limestones of the Lindsay Formation. Areas of the Lindsay Formation which

are overlain by less than 8 m of drift have been selected for possible resource protection. The Lindsay Formation limestone may be suitable for the production of crushed stone or used in cement manufacturing.

Enquiries regarding the Aggregate Resources Inventory of Haldimand and Alnwick Townships may be directed to the Sedimentary and Environmental Geoscience Section, Ontario Geological Survey, Ministry of Northern Development and Mines, 933 Ramsey Lake Road, Sudbury, Ontario, P3E 6B5, or to the Resident Geologist, Ministry of Northern Development and Mines, Bag Service 43, Old Troy Road, Tweed, Ontario, K0K 3J0 [Tel. (613) 478-3161], or to the Lindsay District Office, Ontario Ministry of Natural Resources, 322 Kent Street West, Lindsay, Ontario, K9V 4T7, [Tel. (705) 324-6121].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, HALDIMAND AND ALNWICK TOWNSHIPS*.

1	2	3	4	1	2	3	4	
CLASS NO.	DEPOSIT TYPE (see Appendix C)	AREAL EXTENT Hectares	ORIGINAL TONNAGE Millions of Tonnes	CLASS NO.	DEPOSIT TYPE (see Appendix C)	AREAL EXTENT Hectares	ORIGINAL TONNAGE Millions of Tonnes	
Haldimand Township					G-IC	49	2	
1	G-E	58	14		G-LB	120	4	
	G-E-SF	7	1		G-LD	42	1	
	G-IC	104	21		G-SF-IC	118	4	
	G-SF	97	12		S-E	9	<1	
	G-SF-LB	45	11		S-IC	350	12	
	S-IC	120	15		S-LP	55	2	
	S-M	5700	706	4	S-SF-LB	10	<1	
	S-SF	106	13			8200	910	
2	G-E	7	<1	Alnwick Township				
	G-E-SF	52	5	1	G-E	41	11	
	G-IC	71	6		S-M	3	<1	
	G-LB	24	2	2	S-E	87	6	
	G-SF	72	6		S-IC	175	12	
	S-E	58	4	3	G-IC	139	5	
	S-IC	445	32		S-LP	420	15	
	S-SF	390	28			860	49	
	S-SF-IC	51	4					
	S-SF-LD	64	5	TOTAL FOR REPORT AREA:			9100	960
3	G-E	3	<1					

*Identified deposit areas within the Alderville Indian Reserve No. 37 have been omitted on all tables.

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, HALDIMAND AND ALNWICK TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LICENCED AREA Hectares	5 FACE HEIGHT Metres	6 % GRAVEL	7 REMARKS
LICENCED PITS						
Haldimand Township						
1	T7-124-0	Colin Rutherford	10.99	6-8	30-40	near depletion
2	T7-118-0	George Wimpey Canada Ltd.	68.85	2-3	20-30	near depletion
3	-	County of Northumberland	29.0	3-4	10-30	medium to coarse gravel
4	-	Jean McBride	22.68	3-10	5-30	near depletion, upper 2 to 3 m of fines requires stripping
5	R4-34-0	483990 Ontario Ltd. (Doma)	41.15	-	-	no pit faces
6	R4-20-0	George Wimpey Canada Ltd.	16.2	-	-	rehabilitated
7	R4-21-0	George Wimpey Canada Ltd.	111.78	3-4	20-30	variable from sand and gravel to crushable gravel
8	R4-122-0	Tom Behon	6.08	2-3	20-30	mainly sand with fine to coarse gravel
			306.73			
Alnwick Township						
9	-	Frank Carl Kelly	2.92	2-3	5-20	sand and gravel with some over-size material
10	-	Gerald Finley Construction	18.71	3-4	15-25	sand and gravel with crushable material
11	-	Earl George	11.09	4-5	20-30	sand and gravel with crushable material
12	-	Gerald Finley	3.24	2-3	20-30	near depletion
			35.96			
Total Licenced Area in Report Area:			342.69			
UNLICENCED PITS*						
Haldimand Township						
13	-			1-2	-	sand, rehabilitated, minor oversize gravel seams with clay
14	-			2	-	sand, rehabilitated, minor oversize gravel seams with clay
15	-			3	-	sand, rehabilitated, minor oversize gravel seams with clay

TABLE 2. SAND AND GRAVEL PITTS, HALDIMAND AND ALNWICK TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LICENCED AREA Hectares	5 FACE HEIGHT Metres	6 % GRAVEL	7 REMARKS
16	-			2	-	sand and gravel
17	-			1-4	-	sand
18	-			2-3	-	gravel
19	-			<1.5	-	sand
20	-			2	-	gravel
21	-			5	-	gravel
22	-			3	-	sand only
23	-			<1.5	-	fine sand, some fines, overgrown
24	-			2	-	fine sand
25	-			1-4	-	sandy gravel, over- grown
26	-			1.5	-	sandy gravel
27	-			2	-	sand
28	-			2-4	-	gravel
29	-			2	-	sand with minor gravel, overgrown
30	-			6-7	-	medium sand with gravel and cobbles
31	-			2	-	medium sand with gravel
32	-			1-2	>35	sand and gravel
33	-			5-8	variable	partially overgrown
34	-			2	35	overgrown
35	-			6	>35	gravel with some oversize
36	-			7	<35	sand and gravel, overgrown
37	-			5-6	25	medium sand with gravel
38	-			6	-	gravel, overgrown
39	-			2	-	fine sand
40	-			3-5	-	sand, overgrown
41	-			2-3	variable	sand and gravel
42	-			<1.5	-	sand
43	-			1-2	>35	sand and gravel
44	-			2-7	-	sand with gravel
45	-			1.5	-	medium sand
46	-			2	-	fine and medium sand

TABLE 2. SAND AND GRAVEL PITS, HALDIMAND AND ALNWICK TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LICENCED AREA Hectares	5 FACE HEIGHT Metres	6 % GRAVEL	7 REMARKS
47	-			4	>35	sand and gravel
48	-			2	-	fine sand
49	-			2	-	sand with some gravel, overgrown
50	-			5	-	very fine sand
51	-			2	-	sand
52	-			3	variable	fine sand in west to medium sand with good gravel in east
53	-			2	20	sand
54	-			6-8	>35	sandy in part with good gravel
55	-			4	>35	sand and gravel with oversize
56	-			3	-	sand with some gravel
57	-			<1.5	variable	sand with good gravel
58	-			2	>35	gravel with cobbles, overgrown
59	-			2	10	sand
60	-			2	variable	gravel in pit floor, overgrown
61	-			1-2	variable	sand with gravel pockets, overgrown
62	-			3	>35	gravel with sand, some oversize
63	-			5	variable	sand in south, increasing stone
64	-			5	10	sand
65	-			6	-	sandy with some good gravel
66	-			7	20	sand, overgrown
67	-			3-5	-	gravel and oversize
68	-			2	-	sand
69	-			3	>30	sand and gravel with cobbles
70	-			1.5	-	sand
71	-			2	-	sand with cobbles and oversize, overgrown
72	-			2	-	sand and gravel with some fines and cobbles
73	-			5-6	<20	medium to coarse sand, overgrown
74	-			9	-	fine sand

TABLE 2. SAND AND GRAVEL PITS, HALDIMAND AND ALNWICK TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LICENCED AREA Hectares	5 FACE HEIGHT Metres	6 % GRAVEL	7 REMARKS
75	-			1-3	-	fine sand with gravel, overgrown
76	-			2	-	gravel, some fines
77	-			5	-	sand with gravel, overgrown
78	-			2	-	sandy gravel, over- grown
79	-			3	-	sand with gravel, fines in north face
80	-			2	variable	fine sand with pockets of gravel
81	-			1-2	-	fine sand
82	-			2	-	fine sand, overgrown
83	-			2	-	gravel with oversize, some fines
84	-			5-8	>35	overgrown
85	-			3-4	-	fine sand
86	-			2	-	sand with gravel
87	-			2-3	-	sand with gravel, overgrown
88	-			5	-	sand with oversize and fines, overgrown
89	-			2-3	-	fine sand
90	-			2-3	-	sand with gravel lenses, overgrown
91	-			5	-	sand, overgrown
92	-			1-2	-	sandy fine gravel, overgrown
93	-			2	-	gravel
94	-			2	-	till
95	-			2-7	-	sand
96	-			3	-	sand, some fines
Alnwick Township						
97	-			2	-	sand
98	-			5-6	>35	sand and gravel, overgrown
99	-			2	-	sand
100	-			3-4	>35	sand and gravel
101	-			1-3	<5	fine sand
102	-			2	-	sand with gravel pockets

TABLE 2. SAND AND GRAVEL PITS, HALDIMAND AND ALNWICK TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LICENCED AREA Hectares	5 FACE HEIGHT Metres	6 % GRAVEL	7 REMARKS
103	-			3-9	variable	water in pit floor
104	-			5	variable	sand and gravel, some fines
105	-			3	-	sand with cobbles, overgrown
106	-			2	-	sand, overgrown
107	-			2-5	variable	sand with pockets of gravel
108	-			3-11	variable	sand with gravel, over- grown
109	-			2	>30	sand and gravel overgrown
110	-			5-6	variable	fine to coarse gravel lens
111	-			4	10	sand, partially rehabilitated
112	-			2	15	sand, overgrown
113	-			2	-	sand with some gravel, overgrown
114	-			5	10	sand, overgrown
115	-			5	variable	sand and gravel, very stony in places
116	-			6	variable	sand with good gravel and cobbles in south
117	-			2	variable	fine to medium sand with cobble
118	-			4	-	gravel, overgrown
119	-			1.5	-	fine sand, overgrown
120	-			2	-	fine to medium sand with some fines

* Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, HALDIMAND AND ALNWICK TOWNSHIPS.

1 DEPOSIT NO.	2 UNLICENCED AREA Hectares	3 CULTURAL SETBACKS Hectares	4 EXTRACTED AREA Hectares	5 AVAILABLE AREA Hectares	6 ESTIMATED DEPOSIT THICKNESS Metres	7 AVAILABLE AGGREGATE Millions of Tonnes
1a	28	4	4	20	15	5
1b	6	0	0	6	10	1
	34	4	4	26		6
2a	13	1	0	12	15	3
2b	72	3	0	69	5	6
2c	11	3	4	4	18	1
2d	15	0	1	14	10	2
2e	8	0	0	8	10	1
2f	4	0	0	4	10	<1
2g	7	0	0	7	15	2
2h	52	5	0	47	10	8
	182	12	5	165		23
3a	14	5	7	2	18	<1
3b	14	0	0	14	10	2
	28	5	7	16		2
4	7	2	1	4	10	<1
5a	13	3	0	10	10	2
5b	9	0	0	9	10	2
5c	2	0	0	2	10	<1
5d	4	0	0	4	10	<1
5e	3	0	0	3	20	1
5f	10	2	0	8	10	1
5g	24	3	0	21	15	6
5h	6	0	0	6	10	1
5i	3	0	0	3	10	<1
5j	6	0	0	6	10	1
5k	5	1	0	4	15	1
5l	2	0	0	2	10	<1
5m	2	0	0	2	10	<1
5n	2	0	0	2	5	<1
5o	11	0	0	11	5	1
5p	3	0	0	3	5	<1
	105	9	0	96		16
6a	52	3	0	49	5	4
6b	18	2	0	16	5	1
6c	12	0	0	12	5	1
	82	5	0	77		6
7	41	6	1	34	15	9
TOTAL FOR REPORT AREA:	480	43	18	420		62

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, HALDIMAND AND ALNWICK TOWNSHIPS.

1 DRIFT THICKNESS Metres	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Metres	4 AREAL EXTENT Hectares	5 ORIGINAL TONNAGE Millions of Tonnes
Haldimand Township				
0-1	Lindsay	18	5	2
1-8	Lindsay	18	840	400
8-15	Lindsay	18	1210	580
			2060	980
Alnwick Township				
1-8	Verulam	18	33	16
8-15	Verulam	18	45	21
TOTAL FOR REPORT AREA:			78	37
			2140	1020

TABLE 5. QUARRIES, HALDIMAND AND ALNWICK TOWNSHIPS.

- NONE -

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, HALDIMAND AND ALNWICK TOWNSHIPS.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Metres	3 UNLICENCED AREA Hectares	4 CULTURAL SETBACKS Hectares	5 EXTRACTED AREA Hectares	6 AVAILABLE AREA Hectares	7 ESTIMATED WORKABLE THICKNESS Metres	8 AVAILABLE RESOURCES Millions of Tonnes
1	0-8	840	180	0	660	18	314

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-01**Location:** Haldimand Township, floor of pit no. 1**Type:** Solid-stem auger**Elevation:** Approximately 168 m asl**Date:** January 13, 1992

DEPTH metres	DESCRIPTION
0-0.6	coarse gravel
0.6-1.3	medium sand
1.3-1.6	fine gravel
1.6-2.1	medium sand
2.1-2.4	fine gravel
2.4-3.1	sandy, fine gravel
3.1-4.5	sandy, medium to coarse gravel (water table intersected at 3.8 m)
4.5-5.5	medium sand
5.5-5.8	fine gravel
5.8-7.8	medium sand
7.8-8.6	fine gravel
8.6-8.9	medium sand
8.9-10.2	sandy, fine gravel
10.2-14.4	medium sand
14.4-15.2	stony, clay till

Test Hole Number: HD-TH-02**Location:** Haldimand Township, floor of pit no. 1**Type:** Hollow-stem auger**Elevation:** Approximately 171 m asl**Date:** January 13, 1992

DEPTH metres	DESCRIPTION
0-0.8	sandy, fine gravel
0.8-1.1	medium sand
1.1-3.1	sandy, fine gravel
3.1-5.0	sandy, coarse gravel (water table intersected at 4.0 m)
5.0-5.3	cobble gravel
5.3-5.6	medium sand
5.6-6.1	cobble gravel
6.1-9.0	medium sand
9.0-15.3	clean, fine gravel with minor coarse sand layer
15.3-16.6	clean, coarse gravel
16.6-18.3	medium sand

Test Hole Number: HD-TH-03**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 171 m asl**Date:** January 20, 1992

DEPTH metres	DESCRIPTION
0-1.7	coarse gravel
1.7-2.2	cobble gravel
2.2-3.2	fine gravel
3.2-3.6	medium sand

3.6-5.0

fine gravel

5.0-7.8

cobble gravel

7.8-9.8

medium sand

9.8-12.9

clay

Test Hole Number: HD-TH-04**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 170 m asl**Date:** March 26, 1992

DEPTH metres	DESCRIPTION
0-4.0	mainly fine to coarse gravel with medium to coarse sand matrix

Test Hole Number: HD-TH-05**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 168 m asl**Date:** January 20, 1992

DEPTH metres	DESCRIPTION
0-0.6	pebbly, medium sand
0.6-1.6	sandy, fine gravel
1.6-3.4	fine gravel
3.4-5.2	pebbly, medium sand
5.2-5.9	fine sand
5.9-6.4	cobble gravel
6.4-7.8	medium sand (water table intersected at 7.0 m)
7.8-8.6	fine gravel
8.6-9.6	fine gravel
9.6-10.7	clay

Test Hole Number: HD-TH-06**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 168 m asl**Date:** March 26, 1992

DEPTH metres	DESCRIPTION
0-2.7	cobble gravel
2.7-3.1	coarse sand
3.1-4.3	fine sand

Test Hole Number: HD-TH-07**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 213 m asl**Date:** January 16, 1992

DEPTH metres	DESCRIPTION
0-0.3	fine sand
0.3-0.9	fine gravel
0.9-3.4	fine sand
3.4-4.4	medium sand
4.4-5.1	coarse sand
5.1-6.1	silt

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-08**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 216 m asl**Date:** March 23, 1992

DEPTH metres	DESCRIPTION
0-0.6	medium sand
0.6-0.8	fine gravel
0.8-3.2	cobble to boulder gravel
3.2-3.8	coarse gravel

Test Hole Number: HD-TH-09**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 216 m asl**Date:** January 15, 1992

DEPTH metres	DESCRIPTION
0-1.3	cobble gravel
1.3-1.8	coarse sand
1.8-3.6	cobble gravel
3.6-4.1	medium sand
4.1-5.9	cobble gravel
5.9-7.4	sandy, fine gravel
7.4-8.1	coarse sand
8.1-9.5	cobble gravel
9.5-10.3	medium sand
10.3-10.7	cobble gravel
10.7-13.7	medium sand

Test Hole Number: HD-TH-10**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 206 m asl**Date:** January 15, 1992

DEPTH metres	DESCRIPTION
0-0.5	fine gravel
0.5-2.9	fine sand
2.9-3.6	fine gravel
3.6-4.4	fine sand
4.4-6.1	stony, clay till

Test Hole Number: HD-TH-11**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 201 m asl**Date:** January 15, 1992

DEPTH metres	DESCRIPTION
0-0.7	mainly medium sand with minor fine gravel
0.7-1.2	fine gravel
1.2-1.5	cobble gravel
1.5-2.4	fine gravel
2.4-3.0	medium sand
3.0-4.6	sandy till with occasional large boulders

Test Hole Number: HD-TH-12**Location:** Haldimand Township, 9.1 m W of HD-TH-13**Type:** Hollow-stem auger**Elevation:** Approximately 195 m asl**Date:** January 14, 1992

DEPTH metres	DESCRIPTION
0-8.1	mainly medium sand with few layers of fine gravel <0.3 m thick
8.1-9.5	fine gravel
9.5-10.5	mainly medium sand with some fine gravel
10.5-11.3	sandy till
11.3-11.6	medium sand
11.6-12.2	stony clay till with occasional boulders
12.2-13.9	coarse cobble gravel
13.9-14.6	sandy fine gravel
14.6-14.9	boulder gravel
14.9-16.2	dense stony clay till with occasional boulders

Test Hole Number: HD-TH-13**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 195 m asl**Date:** January 14, 1992

DEPTH metres	DESCRIPTION
0-0.8	fine gravel
0.8-1.1	medium sand
1.1-4.6	mainly fine gravel with occasional thin layers of medium sand <0.3 m thick
4.6-6.9	fine to coarse gravel
6.9-9.1	mainly fine gravel with occasional thin layers of medium sand <0.3 m thick
9.1-9.9	cobble gravel
9.9-10.7	fine gravel
10.7-11.4	boulder gravel (refusal)

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-14**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 195 m asl**Date:** March 23, 1992

DEPTH metres	DESCRIPTION
0-3.7	mainly coarse gravel with few medium sand lenses <0.3 m thick

Test Hole Number: HD-TH-15**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 210 m asl**Date:** March 24, 1992

DEPTH metres	DESCRIPTION
0-3.8	clean, coarse to cobble gravel

Test Hole Number: HD-TH-16**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 198 m asl**Date:** January 16, 1992

DEPTH metres	DESCRIPTION
0-0.5	fine gravel
0.5-0.9	medium sand
0.9-2.1	fine gravel
2.1-2.9	medium sand with few stones
2.9-6.1	medium sand

Test Hole Number: HD-TH-17**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 198 m asl**Date:** March 24, 1992

DEPTH metres	DESCRIPTION
0-1.2	coarse gravel
1.2-2.7	alternating layers of medium to coarse sand <0.3 m thick
2.7-3.7	cobble gravel

Test Hole Number: HD-TH-18**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 198 m asl**Date:** January 16, 1992

DEPTH metres	DESCRIPTION
0-0.9	medium sand
0.9-1.2	fine gravel
1.2-1.6	coarse gravel
1.6-4.7	mainly fine gravel with several medium sand layers <0.6 m thick
4.7-6.0	coarse gravel
6.0-6.9	cobble gravel
6.9-7.9	fine gravel
7.9-9.8	cobble gravel
9.8-10.1	coarse sand
10.1-11.3	cobble gravel
11.3-11.6	medium sand
11.6-13.1	cobble gravel (water table intersected at 13.1 m)
13.1-13.6	medium sand
13.6-15.6	cobble gravel with occasional boulders
15.6-16.9	medium sand with minor fine gravel
16.9-18.3	medium sand

Test Hole Number: HD-TH-19**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 198 m asl**Date:** January 17, 1992

DEPTH metres	DESCRIPTION
0-0.5	cobble gravel
0.5-1.1	sandy, fine gravel
1.1-2.4	cobble gravel
2.4-4.6	medium sand
4.6-5.4	cobble gravel
5.4-6.2	medium sand
6.2-6.6	cobble gravel
6.6-7.6	medium sand
7.6-8.8	cobble gravel
8.8-9.9	boulder gravel (refusal)

Test Hole Number: HD-TH-20**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 198 m asl**Date:** January 17, 1992

DEPTH metres	DESCRIPTION
0-0.9	fine sand
0.9-4.3	fine to coarse gravel
4.3-4.6	boulder gravel (refusal)

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-21**Location:** Haldimand Township, 1.5 m E of HD-TH-20**Type:** Solid-stem auger**Elevation:** Approximately 198 m asl**Date:** January 17, 1992

DEPTH metres	DESCRIPTION
0-1.4	fine sand
1.4-4.5	coarse gravel
4.5-4.9	boulder gravel (refusal)

Test Hole Number: HD-TH-22**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 195 m asl**Date:** January 17, 1992

DEPTH metres	DESCRIPTION
0-3.4	fine sand
3.4-5.5	mainly fine to coarse gravel with several medium sand layers <0.6 m thick (water table intersected at 4.6 m)
5.5-6.7	medium sand
6.7-8.0	coarse gravel
8.0-8.5	medium sand
8.5-9.1	coarse gravel
9.1-9.9	pebbly, coarse sand
9.9-10.7	cobble gravel
10.7-12.2	stony, clay till

Test Hole Number: HD-TH-23**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 226 m asl**Date:** January 17, 1992

DEPTH metres	DESCRIPTION
0-3.2	fine sand
3.2-3.7	coarse sand
3.7-4.9	mainly fine gravel with medium sand
4.9-5.5	coarse gravel
5.5-6.3	mainly fine gravel with medium sand
6.3-7.0	coarse gravel
7.0-7.9	sandy, coarse gravel
7.9-8.3	fine sand
8.3-9.1	sandy, coarse gravel
9.1-9.8	cobble gravel
9.8-10.4	sandy, coarse gravel
10.4-13.5	cobble gravel
13.5-15.2	fine sand to silt

Test Hole Number: HD-TH-24**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 219 m asl**Date:** January 20, 1992

DEPTH metres	DESCRIPTION
0-0.8	fine sand
0.8-3.7	coarse gravel
3.7-4.0	medium sand
4.0-6.7	coarse gravel
6.7-9.3	medium sand
9.3-10.7	coarse gravel
10.7-15.2	fine sand (water table intersected at 14.6 m)

Test Hole Number: HD-TH-25**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 220 m asl**Date:** March 24, 1992

DEPTH metres	DESCRIPTION
0-0.6	fine sand
0.6-3.7	cobble gravel

Test Hole Number: HD-TH-26**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 223 m asl**Date:** March 24, 1992

DEPTH metres	DESCRIPTION
0-0.6	clean, coarse sand
0.6-1.8	fine to coarse gravel
1.8-2.6	fine sand
2.6-3.8	coarse gravel

Test Hole Number: HD-TH-27**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 229 m asl**Date:** January 21, 1992

DEPTH metres	DESCRIPTION
0-1.5	medium sand with few pebbles
1.5-1.7	fine gravel
1.7-3.6	medium sand
3.6-4.6	medium sand with few pebbles
4.6-5.8	medium sand
5.8-6.6	coarse gravel
6.6-7.9	fine to coarse sand
7.9-8.7	coarse gravel
8.7-9.5	medium sand
9.5-10.1	coarse gravel
10.1-12.2	medium sand

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-28**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 232 m asl**Date:** January 21, 1992

DEPTH metres	DESCRIPTION
0-2.1	mainly medium sand with few pebbles
2.1-3.5	coarse gravel
3.5-5.9	mainly medium sand with few pebbles
5.9-10.7	fine sand

Test Hole Number: HD-TH-29**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 229 m asl**Date:** January 21, 1992

DEPTH metres	DESCRIPTION
0-1.5	sandy, fine gravel
1.5-1.9	coarse gravel
1.9-2.5	medium sand
2.5-3.7	fine sand to silt
3.7-4.9	clay
4.9-6.1	fine sand
6.1-6.4	clay
6.4-7.6	fine sand

Test Hole Number: HD-TH-30**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 229 m asl**Date:** January 21, 1992

DEPTH metres	DESCRIPTION
0-2.7	medium sand
2.7-4.0	mainly medium sand with few pebbles
4.0-13.7	medium sand

Test Hole Number: HD-TH-31**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 280 m asl**Date:** January 21, 1992

DEPTH metres	DESCRIPTION
0-0.5	top soil
0.5-1.5	silty, clay till
1.5-6.2	fine sand
6.2-7.0	fine gravel
7.0-8.2	fine sand
8.2-8.9	fine gravel
8.9-9.9	fine sand
9.9-10.7	fine gravel
10.7-19.8	fine sand

Test Hole Number: HD-TH-32**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 270 m asl**Date:** January 21, 1992

DEPTH metres	DESCRIPTION
0-0.6	top soil
0.6-1.4	medium to fine sand
1.4-16.8	fine sand

Test Hole Number: HD-TH-33**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 261 m asl**Date:** January 22, 1992

DEPTH metres	DESCRIPTION
0-0.5	top soil
0.5-2.1	fine sand
2.1-2.4	silt
2.4-6.1	fine sand

Test Hole Number: HD-TH-34**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 261 m asl**Date:** January 22, 1992

DEPTH metres	DESCRIPTION
0-0.5	top soil
0.5-1.7	coarse gravel with occasional boulders
1.7-2.9	medium sand with few stones
2.9-4.6	medium sand
4.6-5.0	fine gravel
5.0-5.3	fine sand (water table intersected at 5.5 m)
5.3-7.6	stony, sandy silt till

Test Hole Number: HD-TH-35**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 264 m asl**Date:** January 22, 1992

DEPTH metres	DESCRIPTION
0-1.4	fine gravel
1.4-2.1	medium sand
2.1-5.6	stony, sandy silt till

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-36**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 264 m asl**Date:** January 22, 1992

DEPTH metres	DESCRIPTION
0-1.5	coarse gravel
1.5-2.0	fine sand
2.0-3.1	fine gravel
3.1-7.0	stony, sandy till

Test Hole Number: HD-TH-37**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 270 m asl**Date:** January 22, 1992

DEPTH metres	DESCRIPTION
0-0.8	cobble gravel with few boulders
0.8-3.1	medium sand
3.1-3.4	stony, sandy silt till
3.4-3.7	medium sand
3.7-4.0	clay
4.0-5.0	medium sand
5.0-9.1	fine sand to silt

Test Hole Number: HD-TH-38**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 284 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-9.8	fine sand
9.8-11.6	sandy, fine gravel
11.6-12.2	fine sand

Test Hole Number: HD-TH-39**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 300 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-0.3	top soil
0.3-18.3	fine sand

Test Hole Number: HD-TH-40**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 274 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-1.6	coarse gravel
1.6-4.6	stony, sandy silt till

Test Hole Number: HD-TH-41**Location:** Haldimand Township, floor of pit no. 4**Type:** Solid-stem auger**Elevation:** Approximately 270 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-0.6	coarse gravel
0.6-1.7	cobble gravel
1.7-3.1	stony, clay till

Test Hole Number: HD-TH-42**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 275 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-4.6	silty, fine sand
4.6-5.9	mainly fine sand with few pebbles
5.9-12.2	silty, fine sand

Test Hole Number: HD-TH-43**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 275 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-0.6	mainly coarse sand with few pebbles
0.6-0.9	medium sand
0.9-3.1	coarse gravel
3.1-4.3	mainly coarse sand with few pebbles
4.3-6.1	fine sand
6.1-6.8	coarse gravel
6.8-7.4	medium sand
7.4-7.9	coarse gravel
7.9-8.4	coarse sand
8.4-9.3	coarse gravel

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-44**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 264 m asl**Date:** March 24, 1992

DEPTH metres	DESCRIPTION
0-0.3	medium sand
0.3-0.9	coarse gravel
0.9-1.1	medium sand
1.1-3.2	coarse gravel
3.2-3.7	medium sand

Test Hole Number: HD-TH-45**Location:** Haldimand Township**Type:** Hollow-stem auger**Elevation:** Approximately 227 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-1.4	fine sand
1.4-1.8	coarse gravel
1.8-2.3	fine sand
2.3-3.4	mainly coarse sand with few pebbles
3.4-4.1	coarse gravel
4.1-5.0	coarse sand
5.0-7.1	cobble gravel with few boulders (refusal)

Test Hole Number: HD-TH-46**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 278 m asl**Date:** March 24, 1992

DEPTH metres	DESCRIPTION
0-1.7	mainly fine gravel with several layers of medium to coarse sand <0.3 m thick
1.7-3.2	coarse gravel
3.2-3.5	fine sand
3.5-4.1	coarse gravel

Test Hole Number: HD-TH-47**Location:** Haldimand Township, 1.5 m N of HD-TH-45**Type:** Solid-stem auger**Elevation:** Approximately 277 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-1.8	fine sand
1.8-3.7	coarse gravel with few cobbles
3.7-4.3	coarse sand
4.3-4.7	fine gravel
4.7-6.4	coarse gravel
6.4-9.0	fine sand
9.0-9.8	fine gravel
9.8-11.6	cobble gravel with occasional boulders (refusal)

Test Hole Number: HD-TH-48**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 280 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-0.6	top soil
0.6-4.6	silt

Test Hole Number: HD-TH-49**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 280 m asl**Date:** January 23, 1992

DEPTH metres	DESCRIPTION
0-0.5	coarse gravel
0.5-0.9	medium sand
0.9-5.6	fine sand
5.6-6.7	fine gravel
6.7-7.6	cobble gravel

Test Hole Number: HD-TH-50**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 280 m asl**Date:** February 6, 1992

DEPTH metres	DESCRIPTION
0-9.1	fine to medium sand
9.1-10.5	medium to coarse sand
10.5-16.8	medium sand
16.8-19.8	pebbly, medium sand

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-51**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 265 m asl**Date:** February 10, 1992

DEPTH metres	DESCRIPTION
0-16.8	medium to fine sand
16.8-18.3	medium sand with few pebbles

Test Hole Number: HD-TH-52**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 253 m asl**Date:** February 6, 1992

DEPTH metres	DESCRIPTION
0-0.9	coarse gravel
0.9-7.8	mainly medium sand with few pebbles
7.8-11.3	cobble gravel
11.3-14.0	mainly medium sand with few pebbles
14.0-18.3	mainly sandy, cobble gravel

Test Hole Number: HD-TH-53**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 250 m asl**Date:** January 24, 1992

DEPTH metres	DESCRIPTION
0-0.8	fine gravel
0.8-1.2	medium sand
1.2-3.7	medium sand with few pebbles
3.7-6.1	fine gravel
6.1-6.7	medium sand
6.7-7.6	fine gravel
7.6-8.1	medium sand
8.1-8.5	fine gravel
8.5-9.3	medium sand
9.3-11.0	coarse gravel
11.0-12.2	medium sand
12.2-13.4	coarse gravel
13.4-15.7	medium sand
15.7-16.8	coarse gravel
16.8-17.4	medium sand
17.4-18.3	coarse gravel

Test Hole Number: HD-TH-54**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 250 m asl**Date:** March 24, 1992

DEPTH metres	DESCRIPTION
0-2.1	medium sand
2.1-3.7	coarse gravel lenses <0.3 m hosted within coarse sand
3.7-4.3	medium sand
4.3-4.6	coarse gravel

Test Hole Number: HD-TH-55**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 240 m asl**Date:** January 24, 1992

DEPTH metres	DESCRIPTION
0-9.1	fine sand

Test Hole Number: HD-TH-56**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 250 m asl**Date:** March 25, 1992

DEPTH metres	DESCRIPTION
0-0.6	sandy fine gravel
0.6-0.9	clean coarse gravel
0.9-2.1	coarse gravel with coarse sand matrix
2.1-3.1	clean coarse gravel
3.1-3.8	fine gravel

Test Hole Number: HD-TH-57**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 252 m asl**Date:** February 10, 1992

DEPTH metres	DESCRIPTION
0-4.9	medium to fine sand
4.9-12.2	fine sand to silt

Test Hole Number: HD-TH-58**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 252 m asl**Date:** February 10, 1992

DEPTH metres	DESCRIPTION
0-14.6	fine to medium sand
14.6-16.2	fine gravel
16.2-21.6	stony, silt till
21.6-22.9	silt to fine sand

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-59**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 300 m asl**Date:** February 10, 1992

DEPTH metres	DESCRIPTION
0-4.0	cobble gravel
4.0-10.7	mainly medium to coarse sand with few pebbles
10.7-12.2	cobble gravel
12.2-18.3	medium to coarse sand

Test Hole Number: HD-TH-60**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 302 m asl**Date:** February 10, 1992

DEPTH metres	DESCRIPTION
0-6.4	mainly medium sand with occasional pebble layers <0.3 m thick
6.4-7.2	coarse gravel
7.2-7.6	medium sand
7.6-8.4	medium to fine sand
8.4-17.0	coarse sand (water table intersected at 10.4 m)
17.0-19.7	silt to fine sand
19.7-21.3	pebbly fine sand

Test Hole Number: HD-TH-61**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 351 m asl**Date:** February 11, 1992

DEPTH metres	DESCRIPTION
0-0.9	coarse gravel
0.9-21.0	fine sand to silt (water table intersected at 17.4 m)
21.0-22.9	sandy silt till

Test Hole Number: HD-TH-62**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 302 m asl**Date:** February 11, 1992

DEPTH metres	DESCRIPTION
0-1.1	cobble gravel
1.1-5.3	fine sand to silt
5.3-6.1	clay
6.1-18.3	fine sand to silt (water table intersected at 9.0 m)

Test Hole Number: HD-TH-63**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 317 m asl**Date:** February 11, 1992

DEPTH metres	DESCRIPTION
0-3.7	medium sand
3.7-4.3	cobble gravel
4.3-7.3	medium sand
7.3-8.4	cobble gravel
8.4-9.1	medium to coarse sand
9.1-10.4	cobble gravel
10.4-20.1	medium to fine sand
20.1-20.9	clay
20.9-22.9	silty clay till

Test Hole Number: HD-TH-64**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 326 m asl**Date:** February 12, 1992

DEPTH metres	DESCRIPTION
0-0.3	top soil
0.3-5.5	medium to coarse sand
5.5-7.9	fine sand to silt
7.9-10.4	boulder gravel
10.4-11.1	medium sand
11.1-12.2	clay till
12.2-14.6	silt
14.6-16.8	silt and clay
16.8-28.4	fine sand and silt
28.4-29.0	stony, clay till

Test Hole Number: HD-TH-65**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 326 m asl**Date:** March 25, 1992

DEPTH metres	DESCRIPTION
0-0.9	coarse gravel
0.9-1.5	fine gravel
1.5-4.0	coarse sand

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-66**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 312 m asl**Date:** February 12, 1992

DEPTH metres	DESCRIPTION
0-3.1	cobble gravel
3.1-8.1	mainly coarse sand with few pebble layers <0.3 m thick
8.1-13.7	cobble gravel
13.7-15.9	medium to coarse sand
15.9-18.3	stony clay till

Test Hole Number: HD-TH-67**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 312 m asl**Date:** March 25, 1992

DEPTH metres	DESCRIPTION
0-1.2	clean boulder gravel
1.2-3.1	clean coarse gravel
3.1-3.7	medium sand

Test Hole Number: HD-TH-68**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 302 m asl**Date:** February 12, 1992

DEPTH metres	DESCRIPTION
0-0.9	coarse gravel
0.9-3.1	medium to coarse sand
3.1-3.4	fine gravel
3.4-11.3	silt to fine sand (water table intersected at 7.6 m)
11.3-13.0	coarse gravel
13.0-16.8	fine to medium sand
16.8-18.4	mainly medium sand with few pebble layers
18.4-24.4	cobble to boulder gravel

Test Hole Number: HD-TH-69**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 290 m asl**Date:** February 12, 1992

DEPTH metres	DESCRIPTION
0-2.6	fine sand
2.6-4.3	silt to clay
4.3-4.6	fine gravel
4.6-10.4	silt
10.4-14.3	medium to coarse sand with few pebbly layers <0.2 m thick
14.3-21.3	medium sand (water table intersected at 19.2 m)

Test Hole Number: HD-TH-70**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 248 m asl**Date:** February 13, 1992

DEPTH metres	DESCRIPTION
0-2.0	fine to medium sand
2.0-7.3	fine sand to silt (water table intersected at 7.3 m)
7.3-13.7	stony, silt to clay till

Test Hole Number: HD-TH-71**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 244 m asl**Date:** February 13, 1992

DEPTH metres	DESCRIPTION
0-0.3	fine gravel
0.3-2.7	fine sand
2.7-6.4	clay
6.4-9.1	silt to fine sand
9.1-21.3	fine sand

Test Hole Number: HD-TH-72**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 248 m asl**Date:** February 13, 1992

DEPTH metres	DESCRIPTION
0-1.5	fine sand
1.5-3.1	silt
3.1-10.7	fine sand to silt
10.7-12.2	clay
12.2-14.3	medium to coarse sand
14.3-15.2	fine gravel
15.2-24.4	fine to medium sand

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-73**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 292 m asl**Date:** February 11, 1992

DEPTH metres	DESCRIPTION
0-1.1	fine gravel
1.1-2.6	fine sand to silt
2.6-3.2	coarse sand
3.2-4.3	coarse gravel
4.3-18.3	fine to medium sand

Test Hole Number: HD-TH-74**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 288 m asl**Date:** February 11, 1992

DEPTH metres	DESCRIPTION
0-12.2	medium and fine sand to silt

Test Hole Number: HD-TH-75**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 285 m asl**Date:** February 11, 1992

DEPTH metres	DESCRIPTION
0-0.5	fine sand
0.5-1.2	fine gravel
1.2-3.4	silt to fine sand
3.4-6.1	fine sand
6.1-16.8	fine to medium sand
16.8-17.4	coarse sand
17.4-18.3	fine gravel
18.3-19.8	medium sand

Test Hole Number: HD-TH-76**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 225 m asl**Date:** February 12, 1992

DEPTH metres	DESCRIPTION
0-0.3	cobble gravel
0.3-6.7	fine sand to silt
6.7-9.8	clay
9.8-11.4	silt
11.4-12.8	medium sand
12.8-13.4	clay
13.4-14.8	medium to coarse sand
14.8-15.2	stony, clay till

Test Hole Number: HD-TH-77**Location:** Haldimand Township**Type:** Solid-stem auger**Elevation:** Approximately 255 m asl**Date:** February 13, 1992

DEPTH metres	DESCRIPTION
0-1.5	coarse gravel
1.5-8.5	fine to medium sand
8.5-10.5	stony, clay till
10.5-18.3	silt to fine sand
18.3-20.6	fine gravel
20.6-22.3	silt to fine sand
22.3-24.4	boulder gravel

Test Hole Number: HD-TH-78**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 312 m asl**Date:** March 25, 1992

DEPTH metres	DESCRIPTION
0-1.4	coarse gravel
1.4-4.1	clean medium sand

Test Hole Number: HD-TH-79**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 171 m asl**Date:** March 26, 1992

DEPTH metres	DESCRIPTION
0-0.3	top soil
0.3-1.8	coarse gravel
1.8-2.4	coarse sand
2.4-2.7	stony, clay till

Test Hole Number: HD-TH-80**Location:** Haldimand Township**Type:** Backhoe**Elevation:** Approximately 171 m asl**Date:** March 26, 1992

DEPTH metres	DESCRIPTION
0-0.2	top soil
0.2-0.9	clean coarse sand
0.9-2.4	boulder gravel
2.4-2.7	stony, clay till

TABLE 7. SUMMARY OF TEST HOLE DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

Test Hole Number: HD-TH-81

Location: Haldimand Township

Type: Backhoe

Elevation: Approximately 171 m asl

Date: March 26, 1992

DEPTH metres	DESCRIPTION
0-0.6	top soil
0.6-1.2	clean coarse gravel
1.2-1.5	fine sand
1.5-1.8	clean fine gravel
1.8-2.6	stony, clay till

Test Hole Number: HD-TH-82

Location: Haldimand Township

Type: Backhoe

Elevation: Approximately 171 m asl

Date: March 26, 1992

DEPTH metres	DESCRIPTION
0-0.3	top soil
0.3-0.8	clean, coarse sand
0.8-1.2	coarse gravel
1.2-1.5	coarse sand
1.5-1.8	fine sand
1.8-2.6	stony, clay till

TABLE 8. SUMMARY OF GEOPHYSICS DATA, HALDIMAND AND ALNWICK TOWNSHIPS.

- NONE -

TABLE 9. RESULTS OF AGGREGATE QUALITY TESTS, HALDIMAND AND ALNWICK TOWNSHIPS.

Sample No.	COARSE AGGREGATE					FINE AGGREGATE	
	Petrographic Number						
	Granular & 16 mm Crushed	Hot Mix & Concrete	Mortar Bar Accelerated Expansion (%)	Magnesium Sulphate Soundness (% Loss)	Absorption (%)	Los Angeles Abrasion (% Loss)	Micro Deval Abrasion (% Loss)
HD-TH-4	119.7	130.8	.058	4	0.67	---	11.0
HD-TH-6	102.8	105.3		3	0.57	25.28	12.9
HD-TH-8a	102.0	108.7		5	0.50	---	10.6
HD-TH-8b	110.5	121.6		6	0.60	25.40	10.7
HD-TH-14a	100.5	101.2		2	0.47	23.52	9.7
HD-TH-14b	100.0	104.0		2	0.47	22.04	10.9
HD-TH-15	122.7	146.3	.070	7	0.60	25.88	14.4
HD-TH-17	109.3	118.6		5	0.57	25.98	10.8
HD-TH-25	106.3	115.2		4	0.67	26.32	12.3
HD-TH-26	108.5	112.9		2	0.47	23.74	10.3
HD-TH-44	102.0	110.2		3	0.54	25.68	10.3
HD-TH-46a	102.1	111.8	.066	4	0.57	24.46	9.9
HD-TH-46b	103.3	106.5		1	0.50	---	10.5
HD-TH-54	101.8	102.9	.074	3	0.40	22.92	11.1
HD-TH-56	104.0	105.1		1	0.43	23.30	9.5
HD-TH-65	112.1	130.9		3	0.77	23.80	10.9
HD-TH-67a	100.5	126.3	.096	4	0.57	22.36	13.8
HD-TH-67b	109.8	142.9		3	0.60	24.48	17.5
HD-TH-67c	102.1	106.0		2	0.54	13.36	12.2
HD-TH-78	110.5	125.8		8	0.71	24.12	19.9
HD-TH-79	108.2	128.1		2	0.64	24.08	12.6
HD-TH-80	113.5	116.1		2	0.60	27.32	9.6

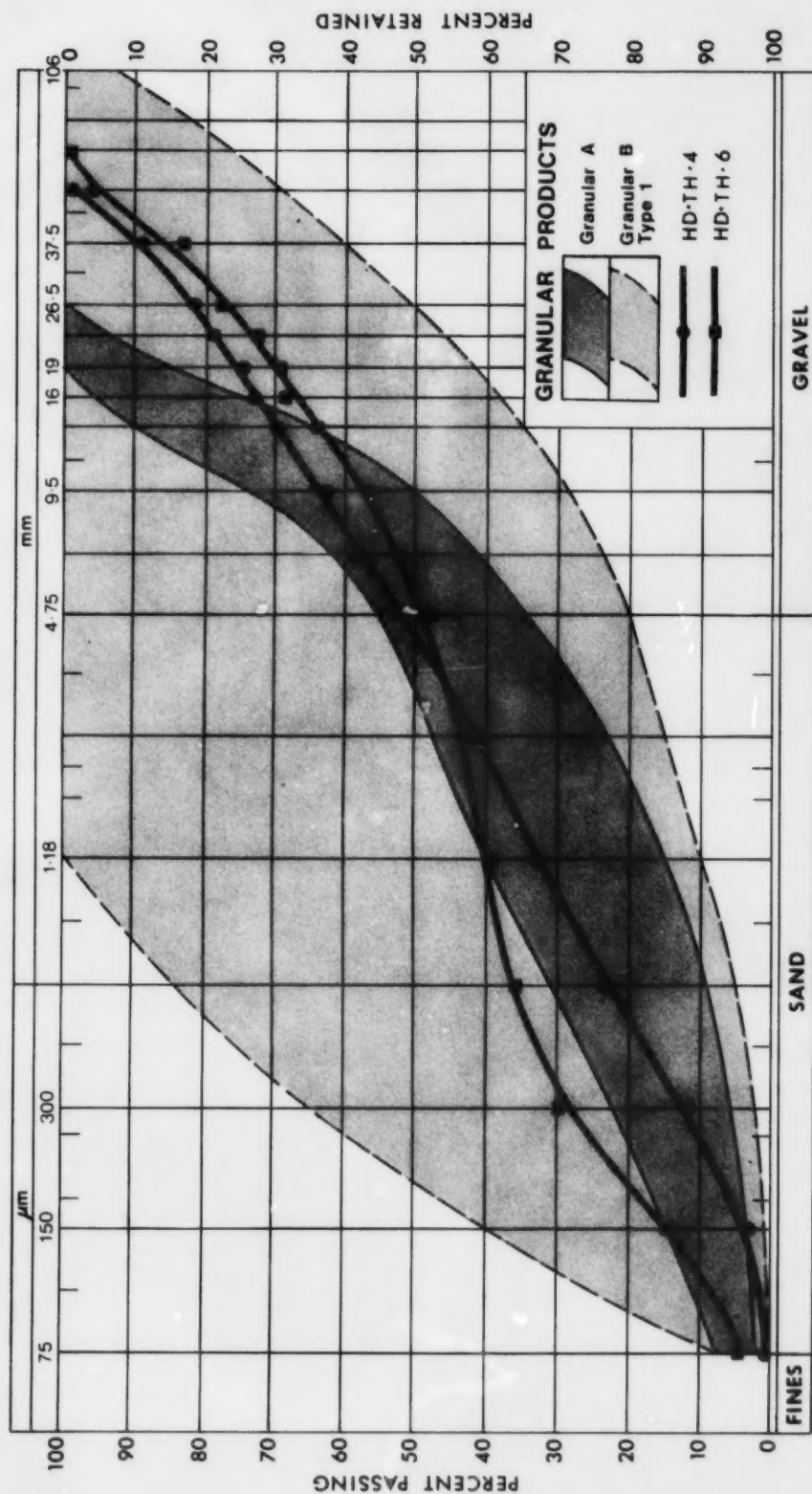


FIGURE 2a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

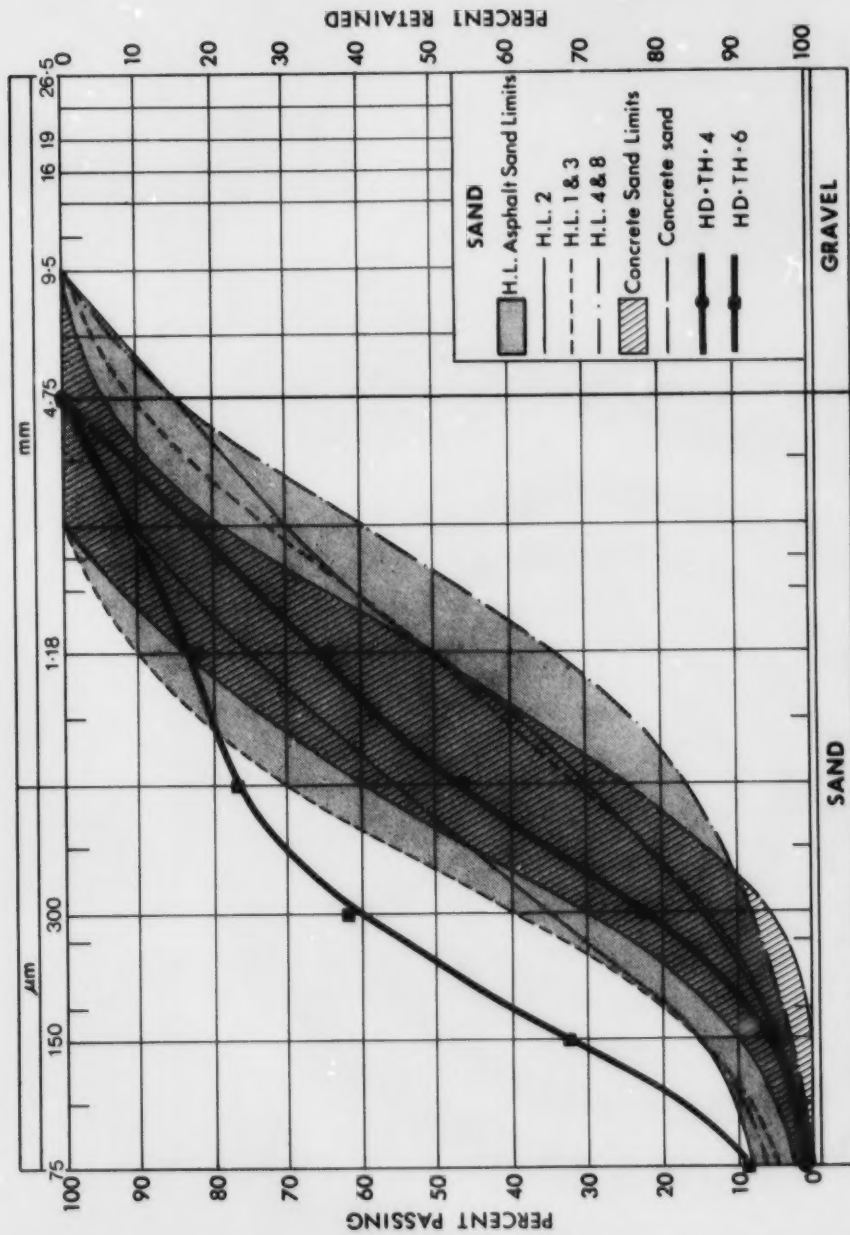


FIGURE 2b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

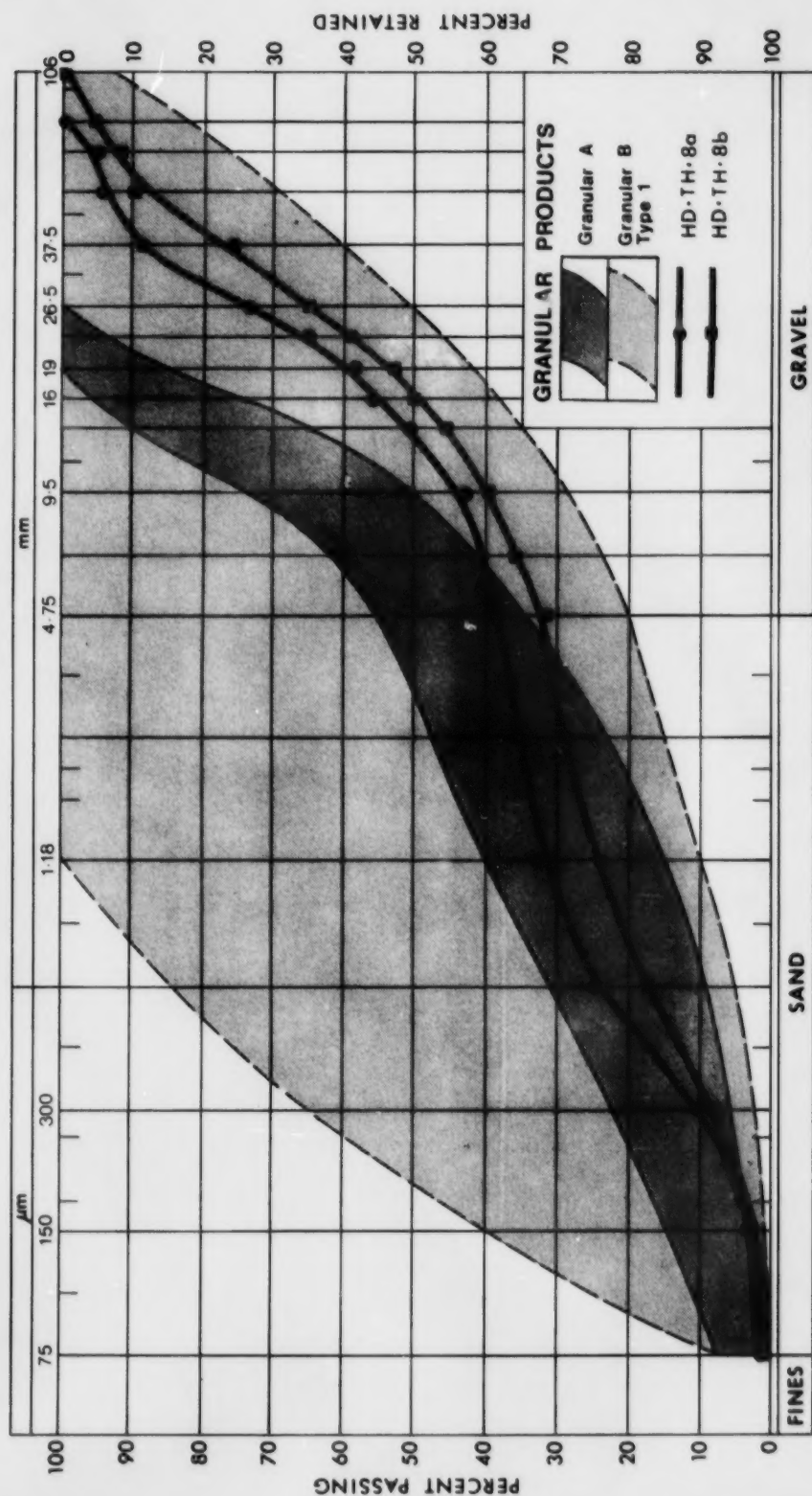


FIGURE 3a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

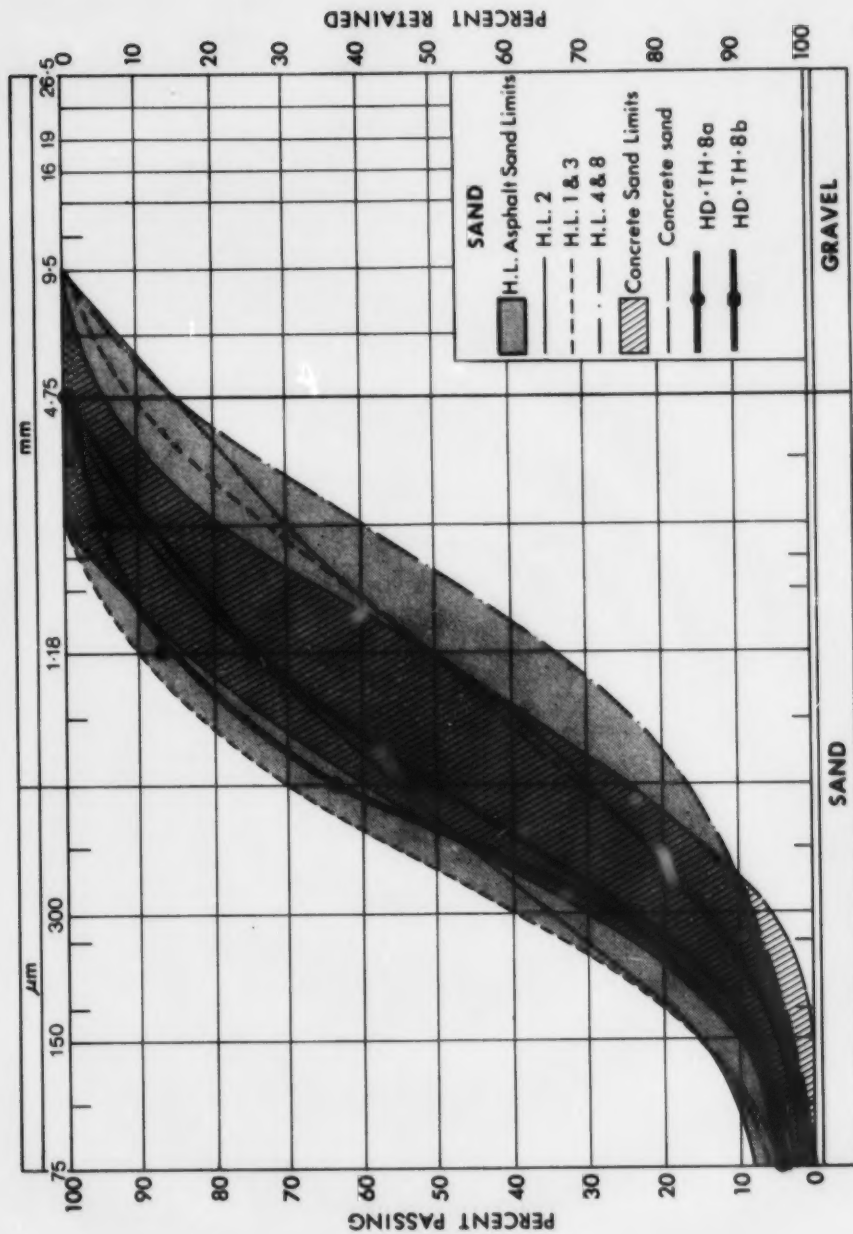


FIGURE 3b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

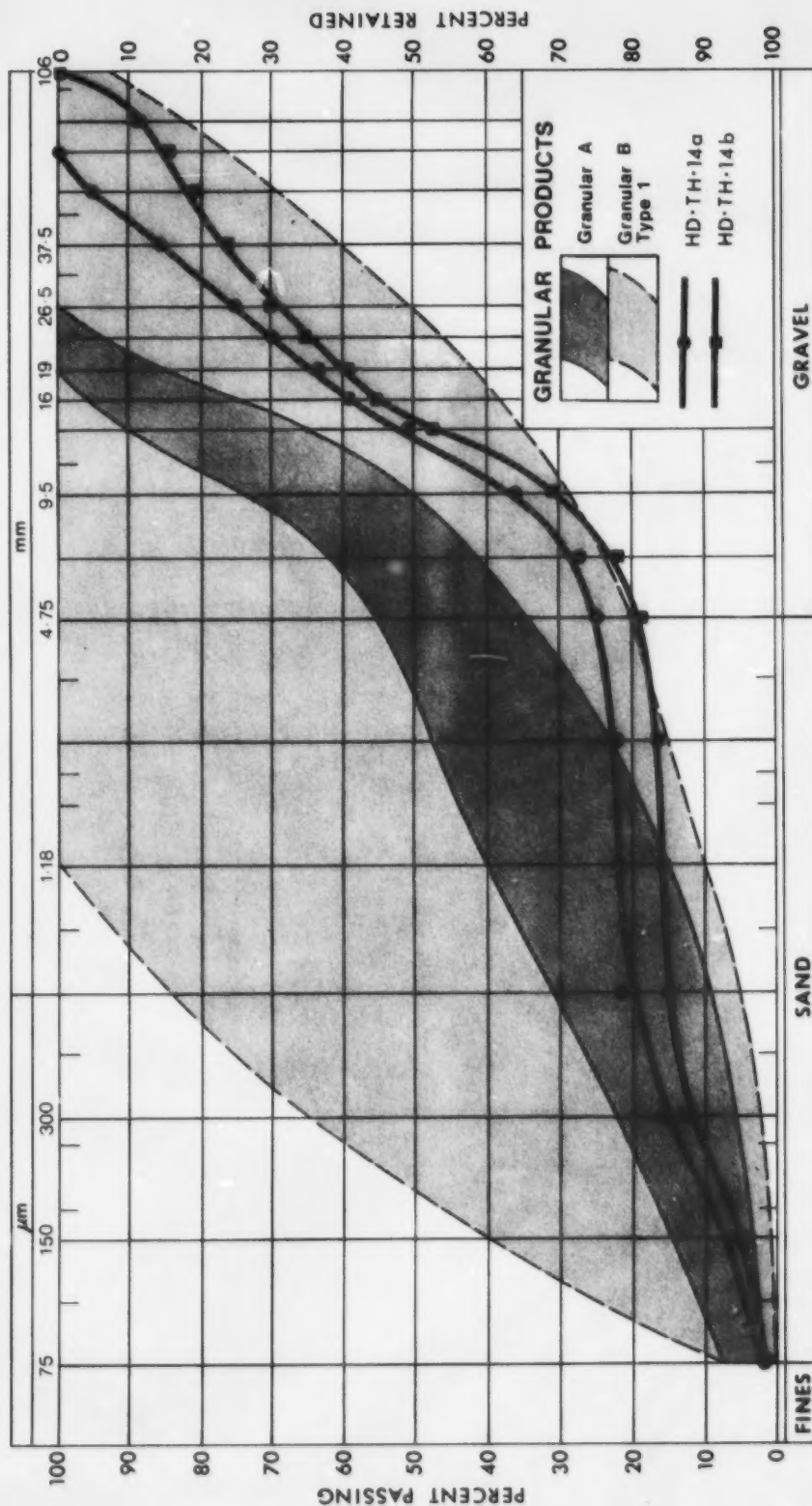


FIGURE 4a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

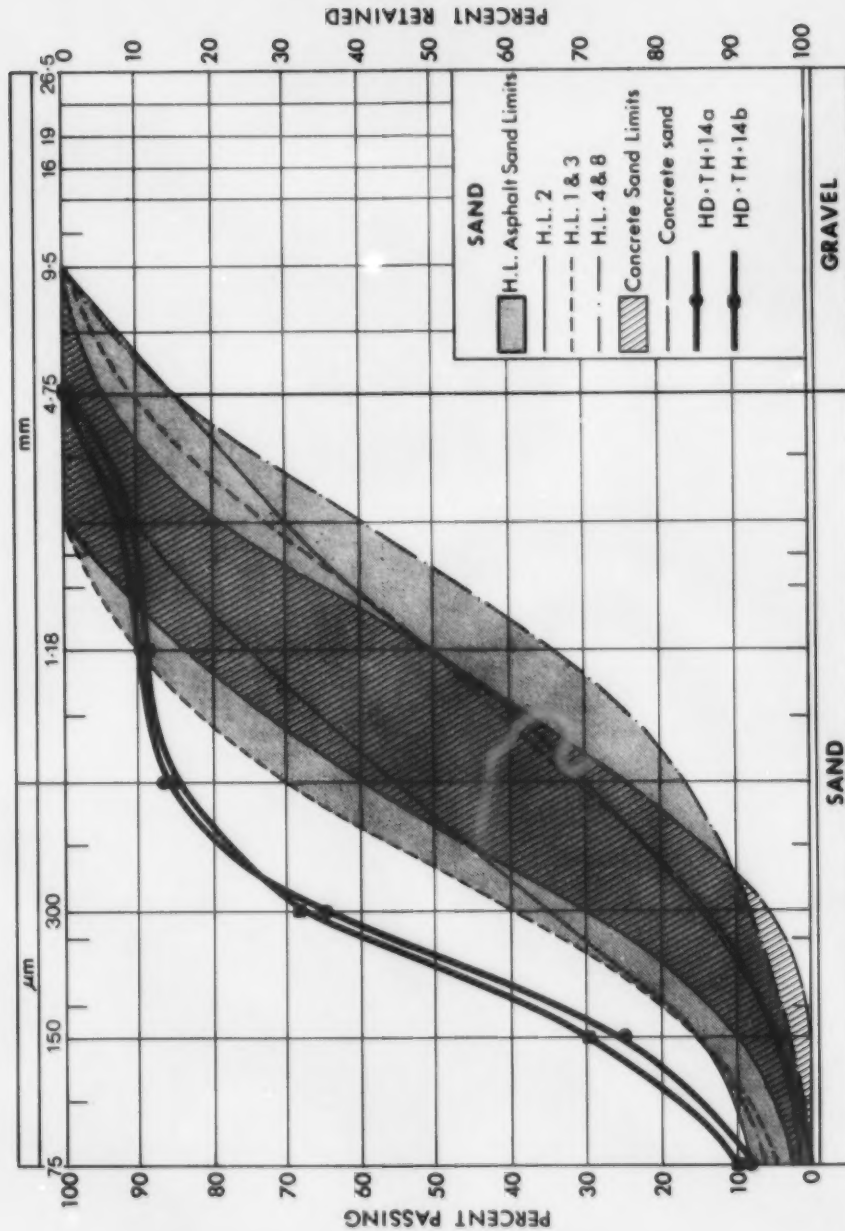


FIGURE 4b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:
Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

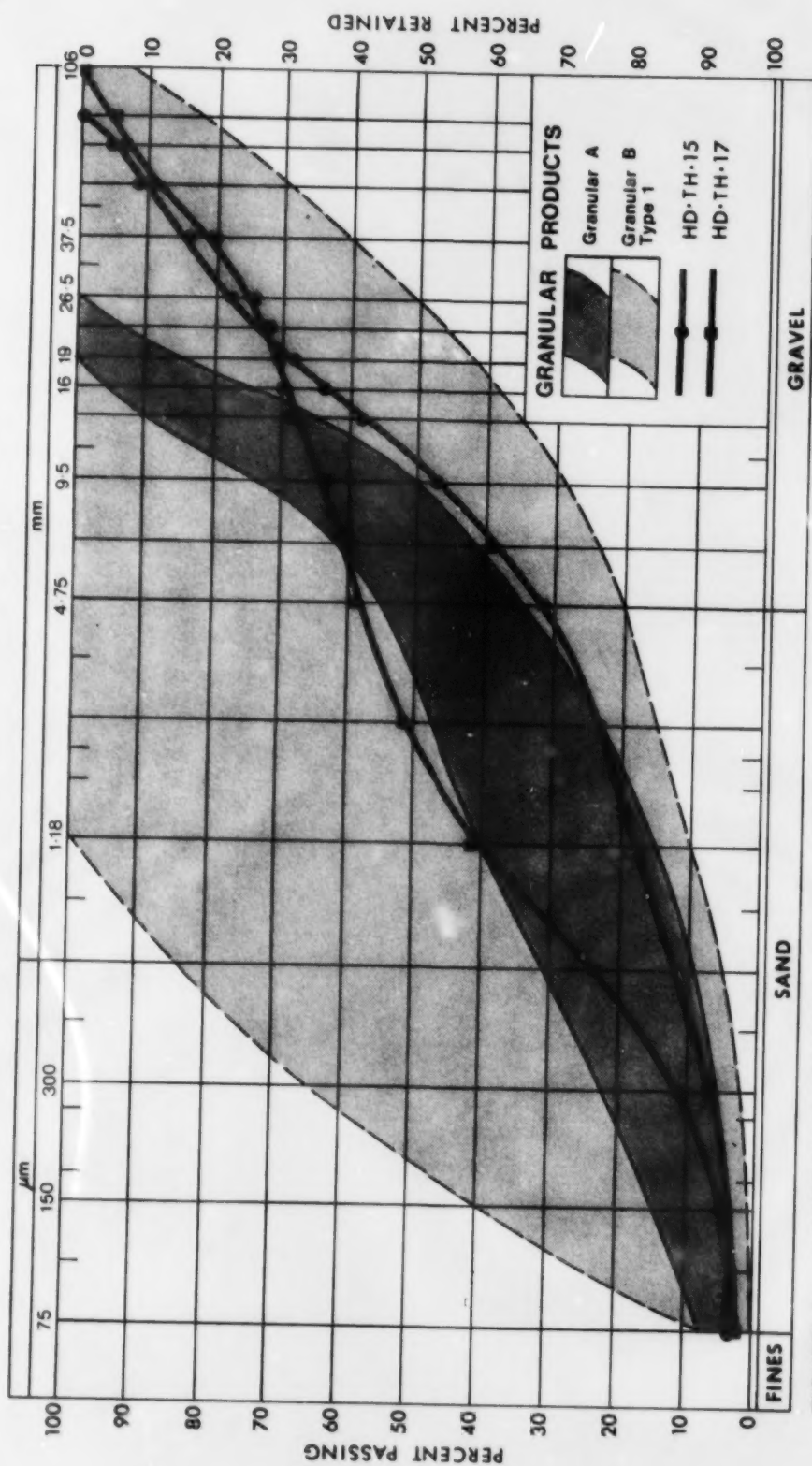


FIGURE 5a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

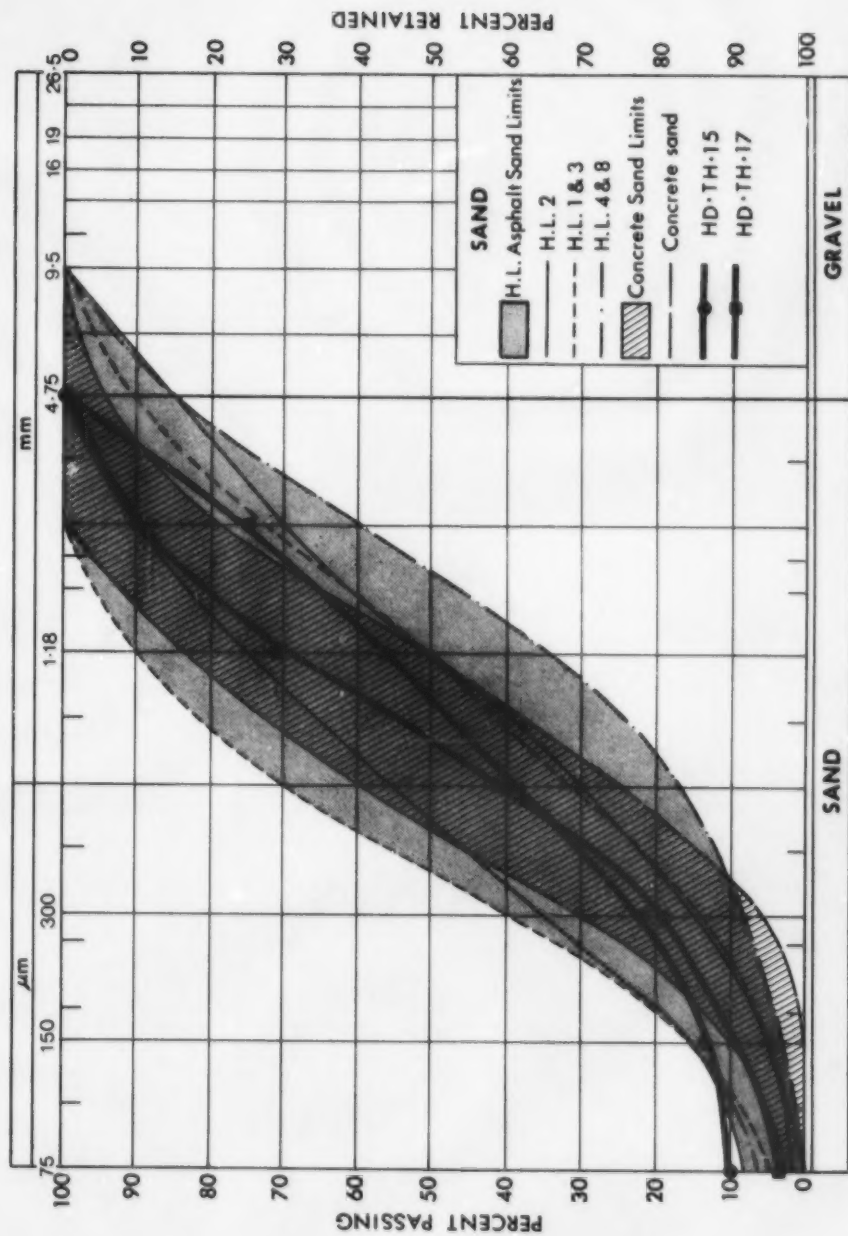


FIGURE 5b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

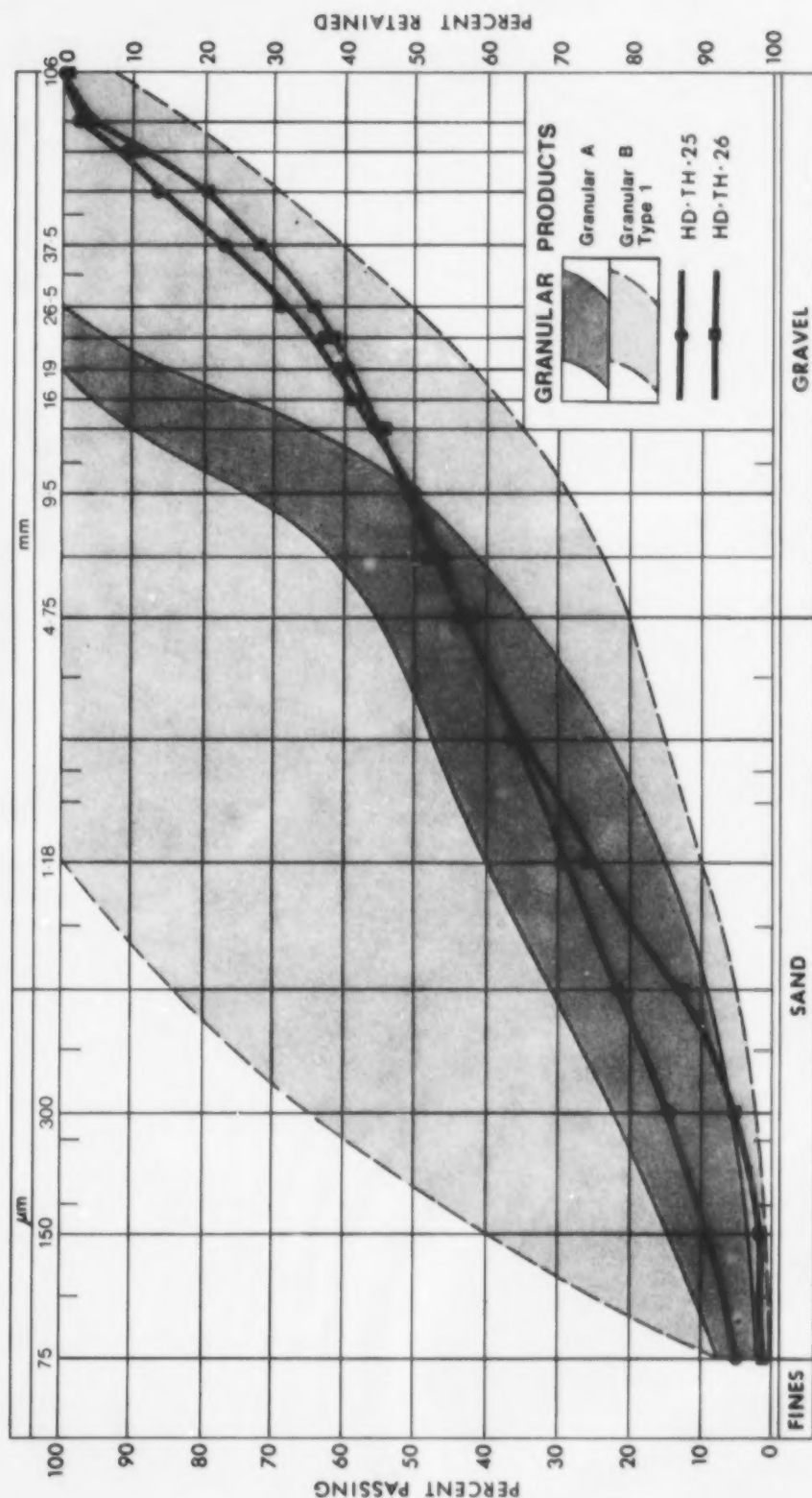


FIGURE 6a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

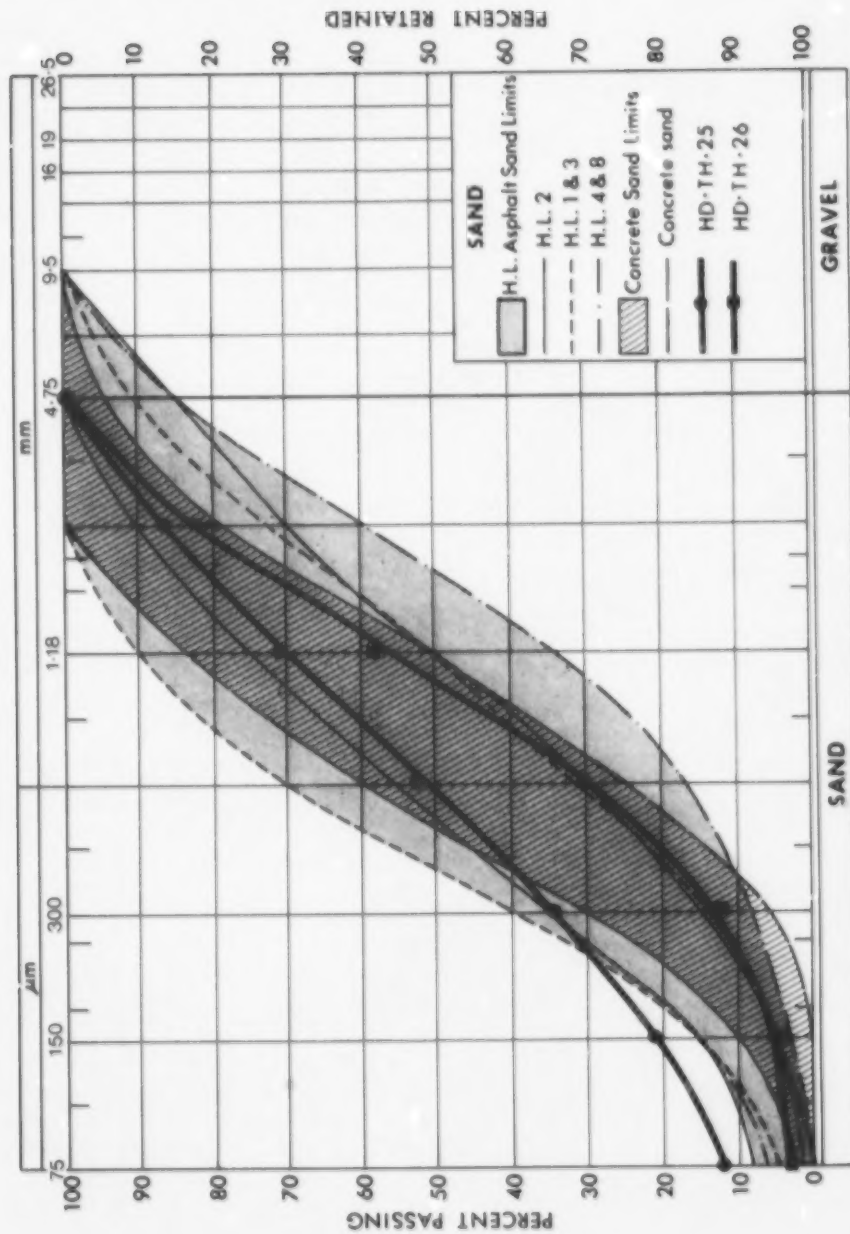


FIGURE 6b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

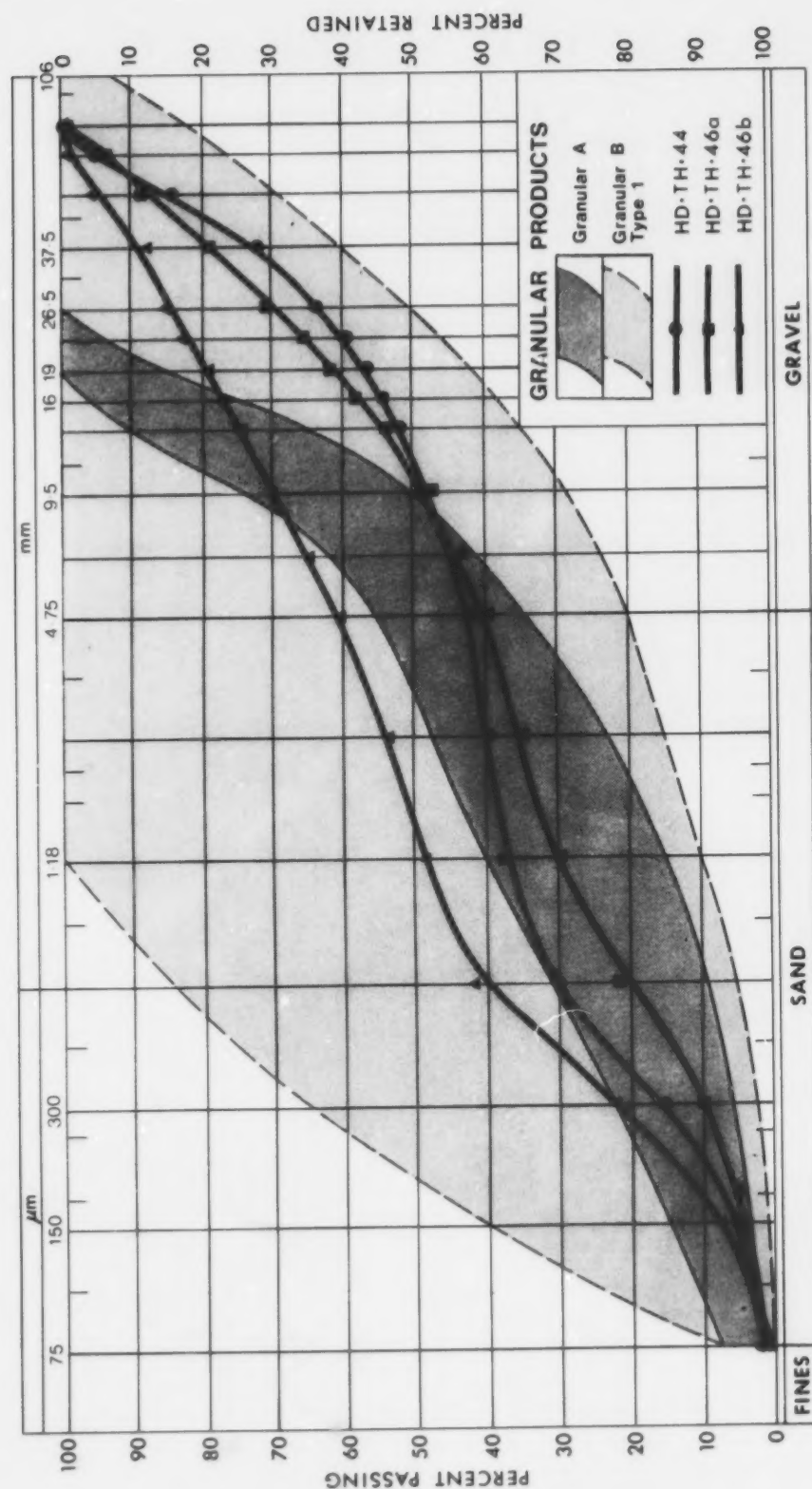


FIGURE 7a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

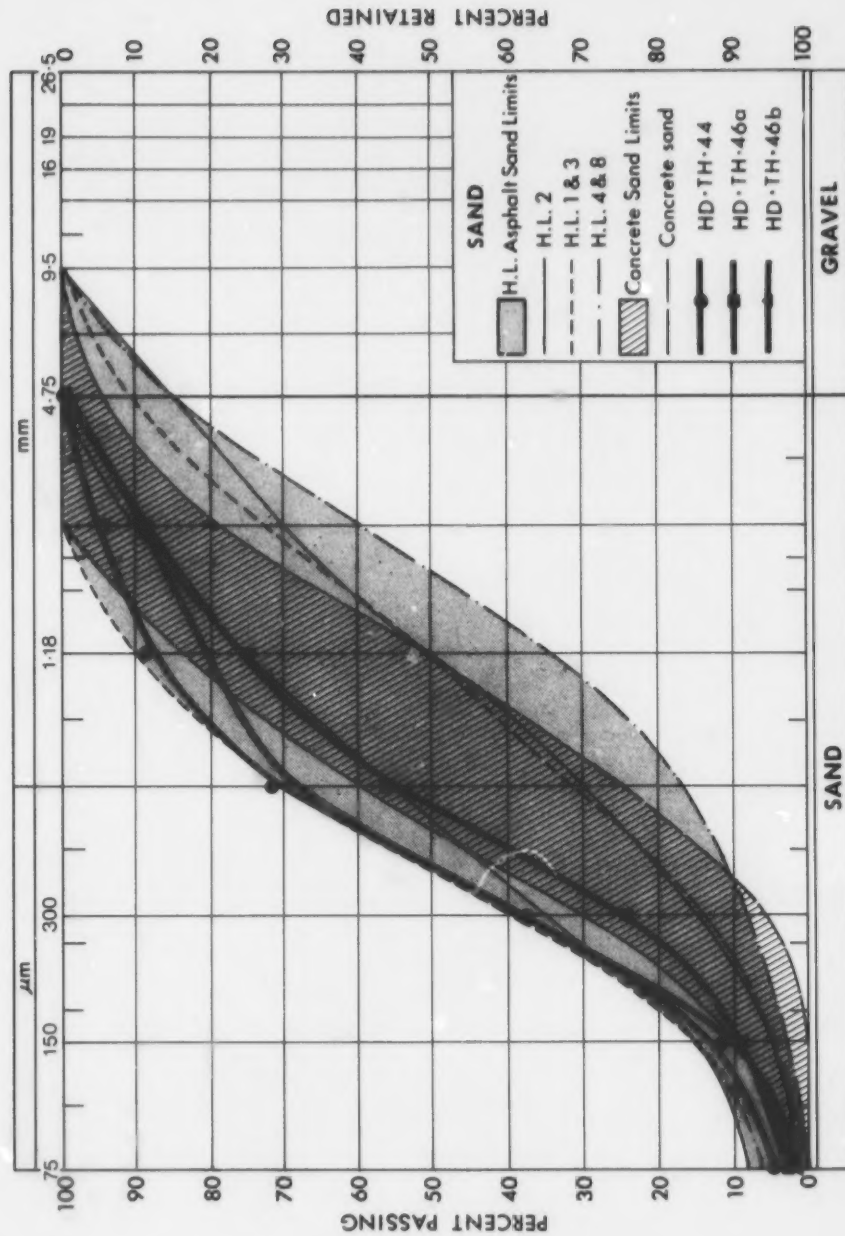


FIGURE 7b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

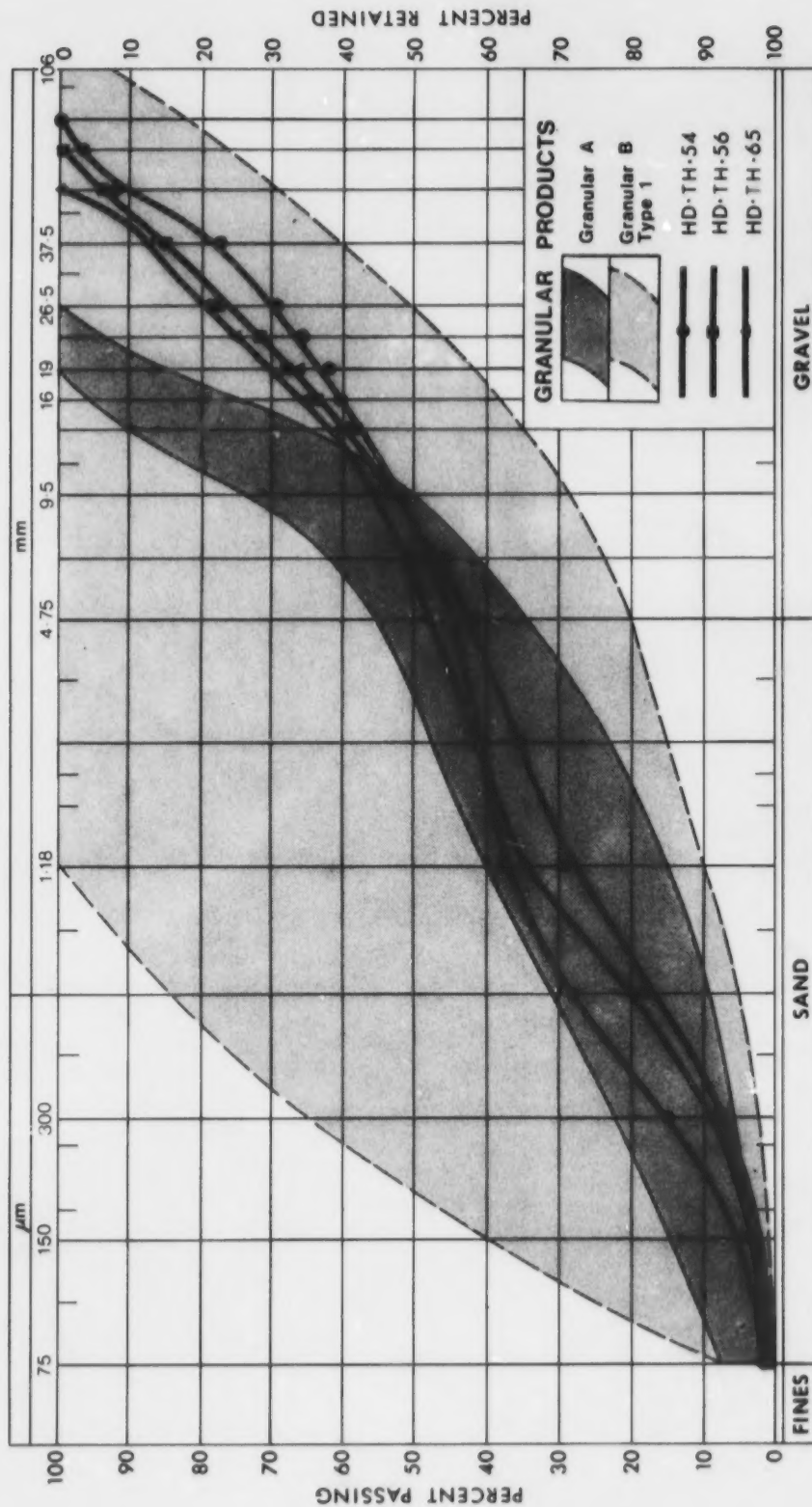


FIGURE 8a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

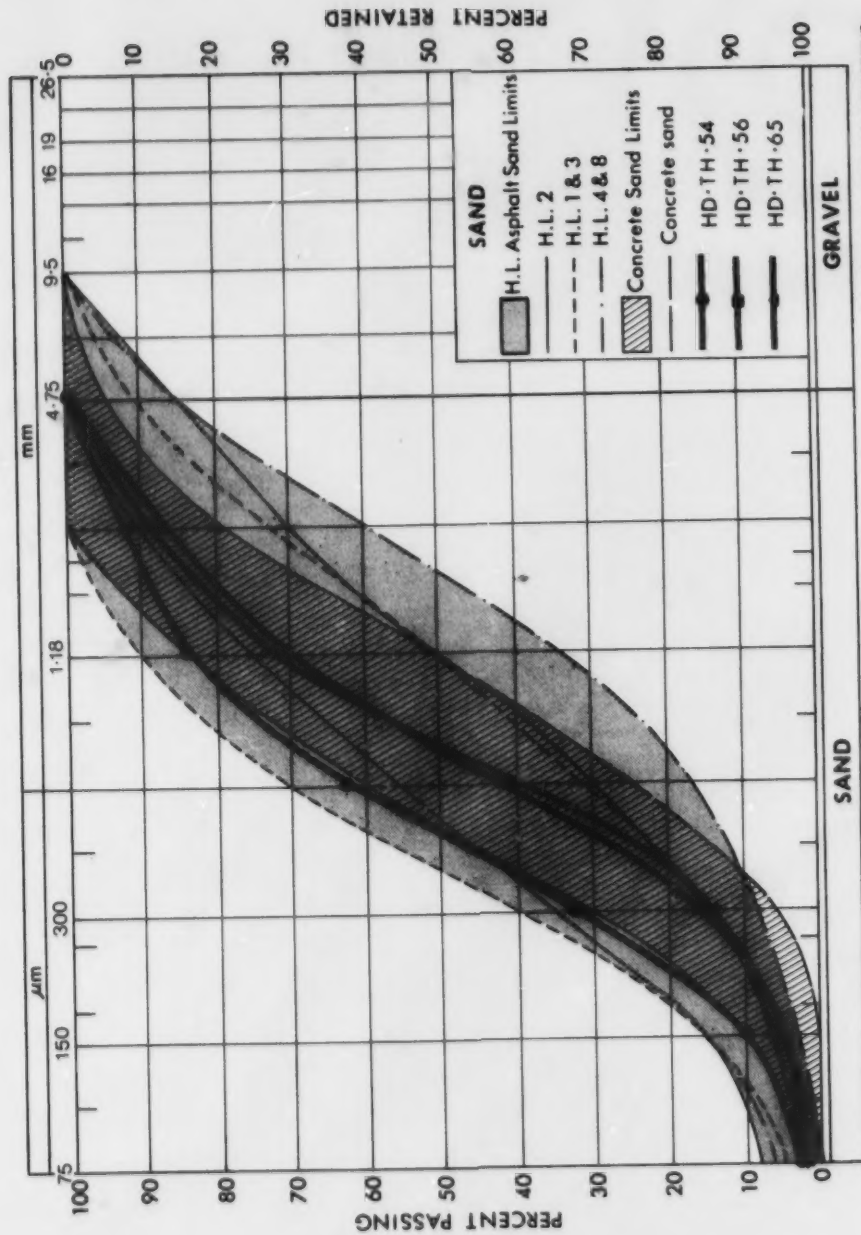


FIGURE 8b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:
Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

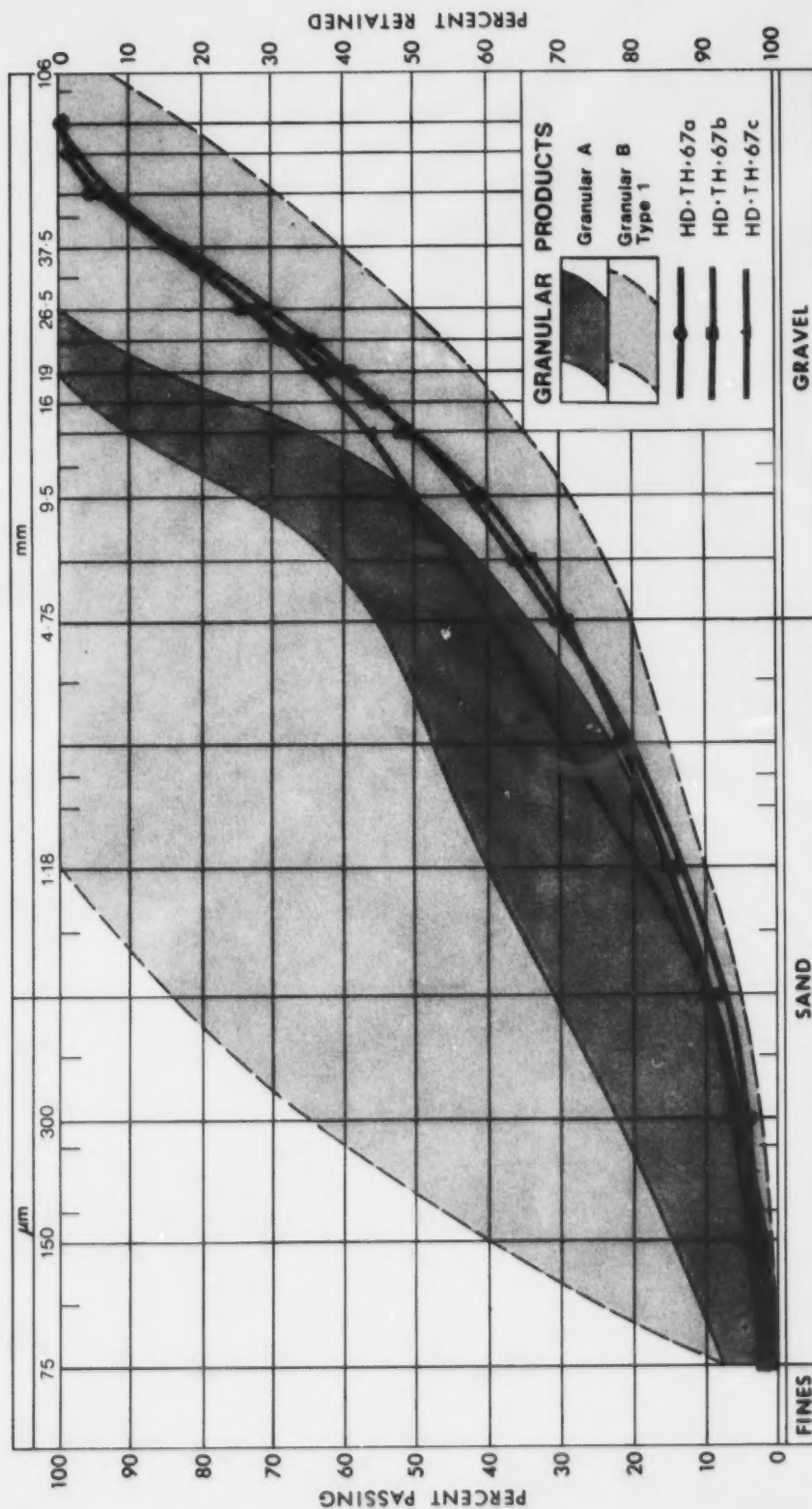


FIGURE 9a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

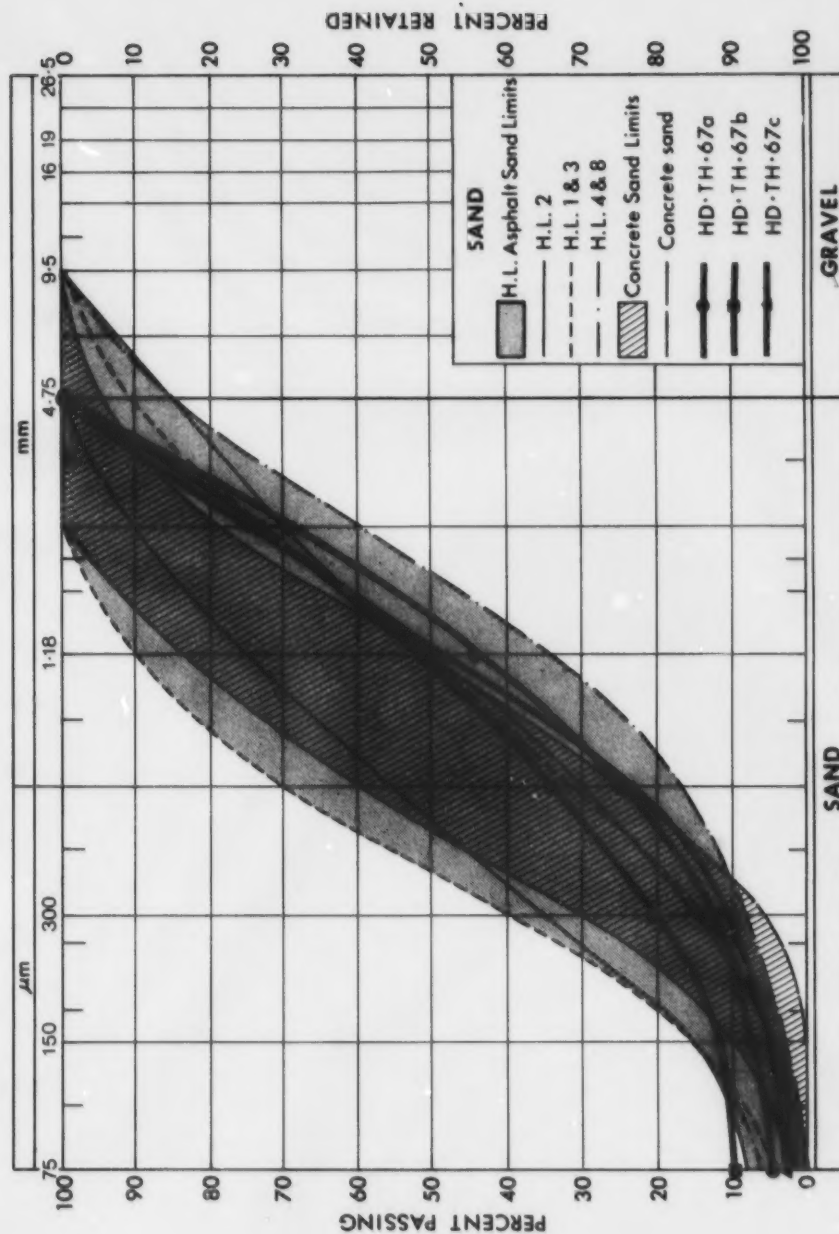


FIGURE 9b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

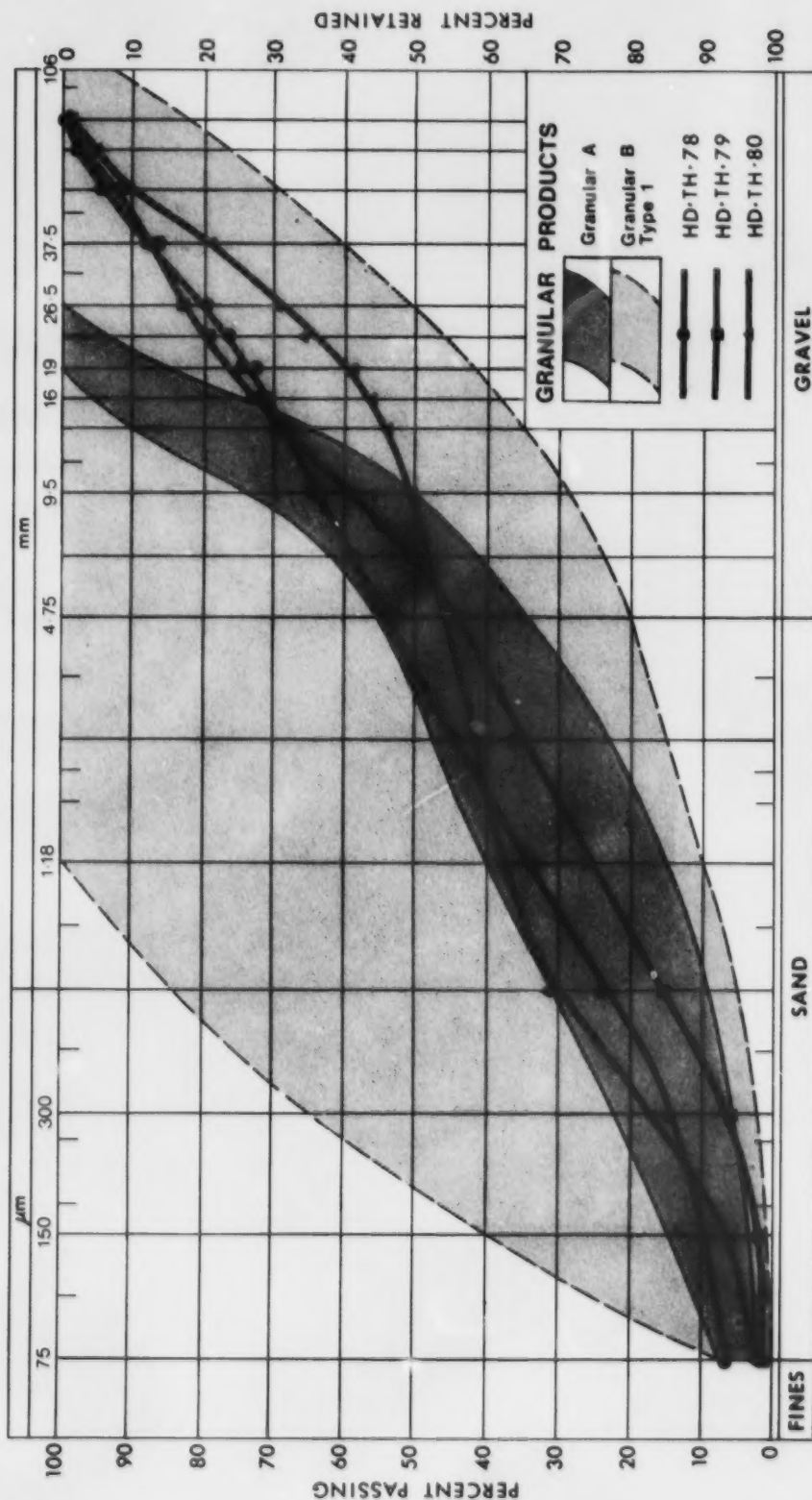


FIGURE 10a. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

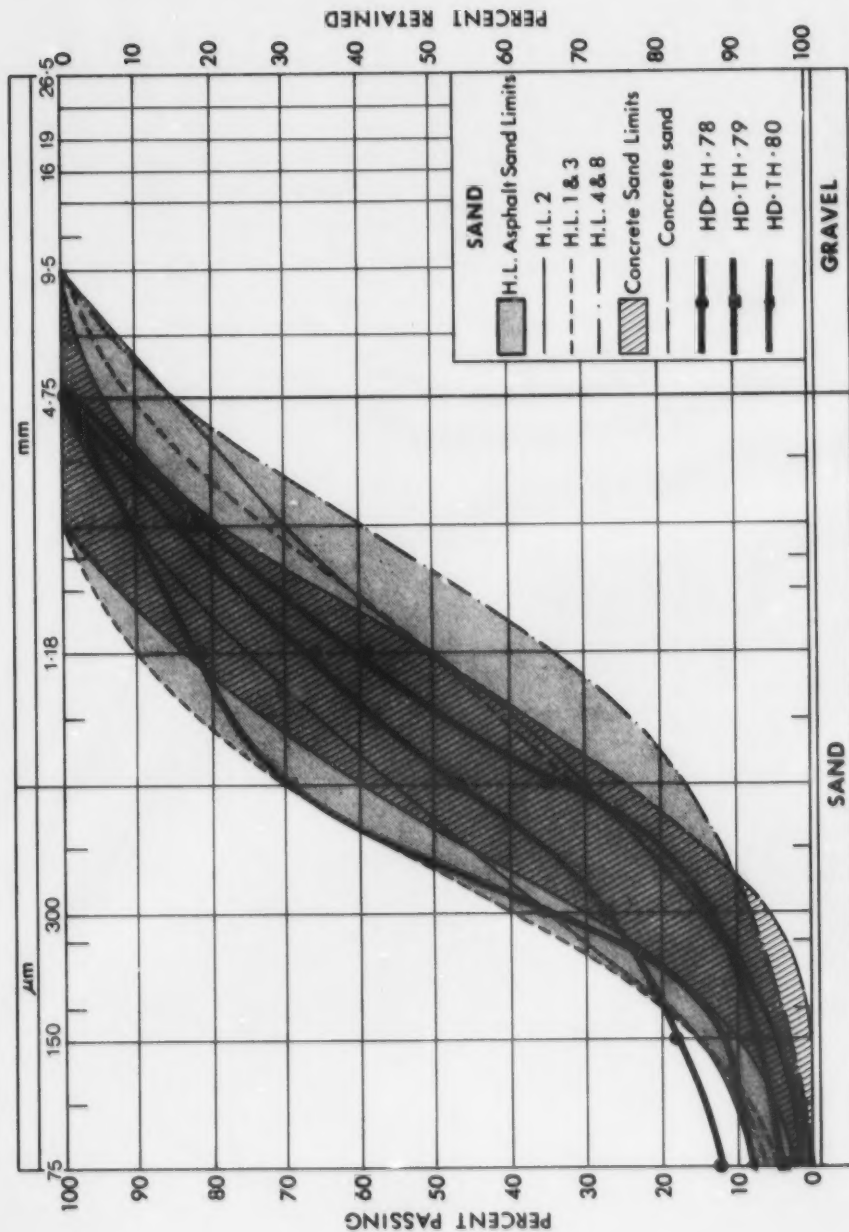


FIGURE 10b. AGGREGATE GRADING CURVES, HALDIMAND AND ALNWICK TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:
Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

References

- Association of Professional Engineers of Ontario 1976. Performance standards for professional engineers advising on and reporting on oil, gas and mineral properties; Association of Professional Engineers of Ontario, 11p.
- Carson, D.M. 1980a. Paleozoic geology of the Rice Lake-Port Hope area, southern Ontario; Ontario Geological Survey, Preliminary Map P.2338, scale 1:50 000.
- 1980b. Paleozoic geology of the Trenton-Consecon area, southern Ontario; Ontario Geological Survey, Preliminary Map P.2375, scale 1:50 000.
- Chapman, L.J. and Putnam, D.F. 1984. The physiography of southern Ontario, 3rd ed.; Ontario Geological Survey, Special Volume 2, 270p.
- Derry Michener Booth and Wahl and Ontario Geological Survey 1989. Limestone industries of Ontario, volume III - limestone industries and resources of central and southwestern Ontario; Ontario Ministry of Natural Resources, Land Management Branch, 175p.
- Gravenor, C.P. 1957. Surficial geology of the Lindsay-Peterborough area, Ontario, Victoria, Peterborough, Durham and Northumberland counties, Ontario; Geological Survey of Canada, Memoir 288, 60p.
- Liberty, B.A. 1960. Rice Lake-Port Hope and Trenton map-areas, Ontario; Geological Survey of Canada, Paper 60-14, 4p.
- 1969. Paleozoic geology of the Lake Simcoe area, Ontario; Geological Survey of Canada, Memoir 355, 201p.
- Ontario Interministerial Committee on National Standards and Specifications (Metric Committee) 1975. Metric practice guide; 67p.
- Ontario Ministry of Municipal Affairs 1992. Municipal directory 1992; Queen's Printer for Ontario, 168p.
- Ontario Ministry of Municipal Affairs and Housing 1983. 1983 municipal directory; Queen's Printer for Ontario, 241p.
- Ontario Ministry of Northern Development and Mines 1989. 1988 Ontario mineral score; Ontario Ministry of Northern Development and Mines, Mineral Development and Lands Branch, 218p.
- Robertson, J.A. 1975. Mineral deposit studies, mineral potential evaluation and regional planning in Ontario; Ontario Division of Mines, Miscellaneous Paper 61, 42p.
- Russell, D.J. and Telford, P.G. 1983. Revisions to the stratigraphy of the Upper Ordovician Collingwood beds of Ontario - a potential oil shale; Canadian Journal of Earth Sciences, v.20, p.1780-1790.
- Taylor, E.B. 1913. The moraine systems of southwestern Ontario; Royal Canadian Institute Transactions, v.10, p.57-79.

Appendix A — Suggested Additional Reading

- Banerjee, I. and McDonald, B.C. 1975. Nature of esker sedimentation; in *Glaciofluvial and Glaciolacustrine Sedimentation*, Society of Economic Paleontologists and Mineralogists, Special Paper No. 23, p.132-154.
- Bates, R.L. and Jackson, J.A. eds. 1987. *Glossary of geology*, 3rd ed.; American Geological Institute, Alexandria, 788p.
- Bauer, A.M. 1970. A guide to site development and rehabilitation of pits and quarries; Ontario Department of Mines, Industrial Mineral Report 33, 62p.
- Cowan, W.R. 1977. Toward the inventory of Ontario's mineral aggregates; Ontario Geological Survey, Miscellaneous Paper 73, 19p.
- Derry Michener Booth and Wahl and Ontario Geological Survey 1989a. Limestone industries of Ontario, volume I — geology, properties and economics; Ontario Ministry of Natural Resources, Land Management Branch, 158p.
- 1989b. Limestone industries of Ontario, volume II — limestone industries and resources of eastern and northern Ontario; Ontario Ministry of Natural Resources, Land Management Branch, 196p.
- 1989c. Limestone industries of Ontario, volume III — limestone industries and resources of central and southwestern Ontario; Ontario Ministry of Natural Resources, Land Management Branch, 175p.
- Fairbridge, R.W. ed. 1968. *The encyclopedia of geomorphology*; Encyclopedia of Earth Sciences, v.3, Reinhold Book Corp., New York, 1295p.
- Flint, R.F. 1971. *Glacial and Quaternary geology*; John Wiley and Sons Inc., New York, 892p.
- Guillet, G.R. and Joyce, I.H. 1987. The clay and shale industries of Ontario; Ontario Ministry of Natural Resources, 157p.
- Hewitt, D.F. 1964a. Building stones of Ontario, part I introduction; Ontario Department of Mines, Industrial Mineral Report 14, 43p.
- 1964b. Building stones of Ontario, part II limestone; Ontario Department of Mines, Industrial Mineral Report 15, 43p.
- 1964c. Building stones of Ontario, part III marble; Ontario Department of Mines, Industrial Mineral Report 16, 89p.
- 1964d. Building stones of Ontario, part IV sandstone; Ontario Department of Mines, Industrial Mineral Report 17, 57p.
- 1972. Paleozoic geology of southern Ontario; Ontario Division of Mines, Geological Report 105, 18p.
- Hewitt, D.F. and Karrow, P.F. 1963. Sand and gravel in southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151p.
- Hewitt, D.F. and Vos, M.A. 1970. Urbanization and rehabilitation of pits and quarries; Ontario Department of Mines, Industrial Mineral Report 34, 21p.
- Lowe, S.B. 1980. Trees and shrubs for the improvement and rehabilitation of pits and quarries in Ontario; Ontario Ministry of Natural Resources, 71p.
- McLellan, A.G., Yundt, S.E. and Dorfman, M.L. 1979. Abandoned pits and quarries in Ontario; Ontario Geological Survey, Miscellaneous Paper 79, 36p.
- Michalski, M.F.P., Gregory, D.R. and Usher, A.J. 1987. Rehabilitation of pits and quarries for fish and wildlife; Ontario Ministry of Natural Resources, Land Management Branch, 59p.
- Ontario Mineral Aggregate Working Party 1977. A policy for mineral aggregate resource management in Ontario; Ontario Ministry of Natural Resources, 232p.
- Ontario Ministry of Natural Resources 1975. Vegetation for the rehabilitation of pits and quarries; Forest Management Branch, Division of Forests, 38p.
- Peat, Marwick and Partners and M.M. Dillon Limited 1981a. Mineral aggregate transportation study; Industrial Mineral Background Paper 1, 133p.
- 1981b. Mineral aggregate transportation study; Industrial Mineral Background Paper 1a, 26p.
- Proctor and Redfern Limited 1974. Mineral aggregate study, central Ontario planning region; prepared for the Ontario Ministry of Natural Resources, 200p.
- Proctor and Redfern Limited and Gartner Lee Associates Limited 1975. Mineral aggregate study and geological inventory of part of the eastern Ontario region; prepared for the Ontario Ministry of Natural Resources, 326p.
- 1977. Mineral aggregate study and geological inventory, southwestern region of Ontario; prepared for the Ontario Ministry of Natural Resources, 246p.
- Rogers, C.A. 1985a. Alkali aggregate reactions, concrete aggregate testing and problem aggregates in Ontario—a review, 5th revised ed.; Ontario Ministry of Transportation and Communications, Engineering Materials Office, Report EM-31, 44p.
- 1985b. Evaluation of the potential for expansion and cracking due to the alkali-carbonate reaction; in *Cement, Concrete and Aggregates*, CCAGDP, v.8, no.1, p.13-23.

Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate reaction: A chemical reaction between the alkalis of Portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often nondurable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35% coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20% greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex

arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular Base and Subbase: Components of a pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Four types have been defined: Granular A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular B which is usually pit-run or other unprocessed aggregate, Granular M is a shouldering and surface dressing material with quality requirements similar to Granular A, and Select Subgrade Material has similar quality requirements to Granular B and it provides a stable platform for the overlying pavement structure. (For more specific information the reader is referred to Ontario Provincial Standard Specification OPSS 1010).

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (HL 1, 3 and 4), or as binder course (HL 2 and 8) used to bind the surface course to the underlying granular base.

Lithology: The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to

15% indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abrasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering

processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsin time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers, consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain

size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Subaqueous Fan (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan or lobe shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain.

The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large post-glacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 6 m thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario, such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sedi-

ments which form the plain are predominantly fine to medium sand, silt and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular subbase aggregate.

GLACIAL DEPOSITS

Moraines (M): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness and uses of the

formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, MgSO_4 = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded noncalcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 14 m. USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 30 m. USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, MgSO_4 = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 18 to 60 m. USES: quarried extensively for aggregate in areas of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate; suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, MgSO_4 = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaly interbeds. THICKNESS: 61 to 102 m. USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, MgSO_4 = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 125 m. USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, MgSO_4 = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: in eastern Ontario, the basal unit of the Ottawa Group; in central Ontario, overlain by the Simcoe Group. COMPOSITION: in eastern Ontario, silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario,

conglomerates, sandstones and shales. THICKNESS: in eastern Ontario, 2 to 3 m; in central Ontario, 0 to 12 m. USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario, the formation is subdivided into upper and lower members; west of Lake Simcoe, it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario, the lower member consists of alternating units of limestone, dolomitic limestone and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe, the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone, whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 7 to 62 m. USES: quarried in the Lake Simcoe, Kingston, Ottawa and Cornwall areas for crushed stone; rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 24 to 87 m. USES: quarried at Brechin, Marysville and in the Ottawa area for crushed stone; generally suitable for use as granular base aggregate; rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 32 to 70 m. USES: quarried at Picton and Bath for use in cement manufacture; quarried for aggregate in Mara Township, Simcoe County and in the Belleville-Kingston area; may be unsuitable for use as aggregate

in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa groups; in eastern Ontario, it is divisible into an unnamed lower member and the Eastview Member; in central Ontario, it is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: in eastern Ontario, the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; in central Ontario, Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 25 to 61 m. USES: in eastern Ontario, the lower member is used extensively for aggregate production; in central Ontario, it is quarried at Picton, Ogden Point and Bowmanville for cement; may be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: in central Ontario, Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; in eastern Ontario, Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: the Blue Mountain Formation is blue-grey, noncalcareous shale; Billings Formation is dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 43 to 61 m; Billings Formation - 0 to 62 m. USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: in central Ontario, the Georgian Bay Formation is composed of interbedded limestone and shale; in eastern Ontario, the Carlsbad Formation is composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation - 91 to 170 m; Carlsbad Formation - 0 to 186 m. USES: Georgian Bay Formation is used by several pro-

ducers in Metropolitan Toronto area to produce brick and structural tile, as well as for making Portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate; Carlsbad Formation is used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 122 to 152 m. USES: there are several large quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa; all extract shale for brick manufacturing; the Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Peninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 8 m. USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff brown dolomitic limestones and dolostones. THICKNESS: 0 to 23 m. USES: extracted for crushed stone in St. Vincent Township, Grey County and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: no data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 15 to 18 m; USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile; lack of suitable exposures has limited its use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 15 m. USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 2 to 3 m. USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION: dark grey to green shale with minor interbedded limestone. THICKNESS: 0 to 2 m. USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 6 m. USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 11 m. USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 26 m. USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4 = 1-2$, $LA = 19-21$, $Absn = 0.6-0.7$, $BRD = 2.78-2.79$, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part, to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment, as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation is fine- to coarse-crystalline dolostone with high silica content; Reynales Formation is thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation - 6 to 26 m; Reynales Formation - 0 to 3 m. USES: both formations quarried for aggregate with overlying Amabel and Lockport formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4 = 41$, $LA = 29$, $Absn = 4.1$, $BRD = 2.45$, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. **COMPOSITION:** massive, coarse-crystalline crinoidal limestone. **THICKNESS:** 0 to 2 m. **USES:** not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. **COMPOSITION:** black to dark grey calcareous shale with numerous limestone lenses. **THICKNESS:** 5 to 18 m. **USES:** not significantly utilized. **AGGREGATE SUITABILITY TESTING:** PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Absn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. **COMPOSITION:** sandy to shaly dolomitic limestone and dolostone. **THICKNESS:** 0 to 5 m. **USES:** too shaly for high quality uses, but is quarried along with Lockport Formation in places. **AGGREGATE SUITABILITY TESTING:** PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Warton/Colpoy Bay and Eramosa members. **COMPOSITION:** Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin-bedded to massive, medium-crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. **THICKNESS:** (Lockport/ Amabel) 3 to 40 m. **USES:** both formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. **AGGREGATE SUITABILITY TESTING:** PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. **COMPOSITION:** micro-crystalline to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity.

THICKNESS: 30 to 52 m. **USES:** some areas appear soft and unsuitable for use in the production of load-bearing aggregate; this unit requires additional testing to fully establish its aggregate suitability; main use is for dolomitic lime for cement manufacture; quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; rarely exposed at the surface. **COMPOSITION:** grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. **THICKNESS:** 113 to 183 m. **USES:** gypsum mines at Hagersville, Caledonia and Drumbo; salt is mined at Goderich and Windsor and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville and Akron members. **COMPOSITION:** medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. **THICKNESS:** 14 to 49 m. **USES:** quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high-specification aggregate because of low freeze-thaw durability; has also been extracted for lime. **AGGREGATE SUITABILITY TESTING:** PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. **COMPOSITION:** thick- to massive-bedded, coarse-grained, grey-yellow sandstone. **THICKNESS:** 0 to 5 m. **USES:** has been quarried for silica sand, building stone and armour stone; may be acceptable for use as rip rap and well cemented varieties may be acceptable for some asphaltic products. **AGGREGATE SUITABILITY TESTING:** (of a well cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. **COMPOSITION:** a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. **THICKNESS:** 3 to 40 m.

USES: quarried at Hagersville, Cayuga and Port Colborne for crushed stone; material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence and Moorehouse members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish brown, variably cherty limestone. THICKNESS: 18 to 25 m. USES: quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne; high chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete; has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Peninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone and dolostone with grey chert nodules; Formosa Reef Limestone is high purity (calcium-rich) limestone; Sylvania Sandstone Member is quartz sandstone. THICKNESS: 0 to 50 m; Formosa Reef Limestone up to 26 m. USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminous laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone. THICKNESS: 40 to 75 m. USES: most important source of high-purity limestone in Ontario; used as calcium lime for metallurgical flux and for the manufacture of chemicals; rock of lower purity is used for cement manufacture, agricultural lime and aggregate; Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn =

1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers and chert in some areas. THICKNESS: 15 to 30 m. USES: quarried near Port Dover and on Pelee Island for crushed stone; used at St. Marys as a raw material for Portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 5 m. USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no outcrop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 9 m. USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 6 m. USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 5 to 37 m. USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 2 m. USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous cal-

careous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 14 m. USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse-grained, grey-brown, bioclastic limestone. THICKNESS: 2 to 14 m. USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 61 m. USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 33 m. USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine- to medium-grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 60 m. USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 20 m. USES: no present uses.

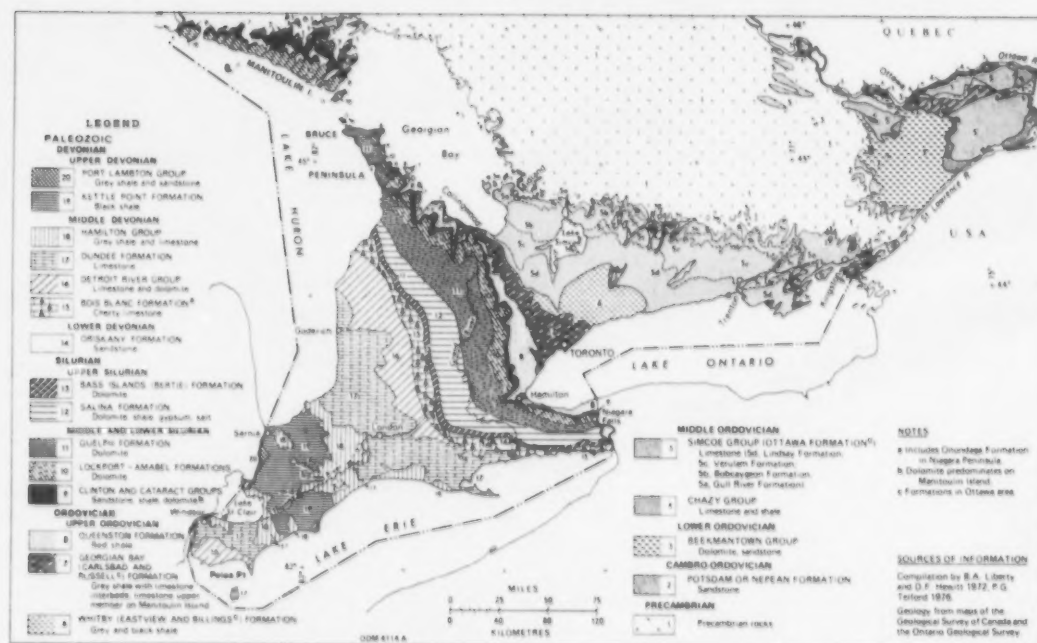
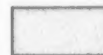


Figure D1. Bedrock geology of southern Ontario.

		SOUTHWESTERN ONTARIO	NIAGARA PENINSULA SIMCOE - NIAGARA FALLS	NIAGARA ESCARPMENT NORTH OF HAMILTON TO MANITOULIN ISLAND	CENTRAL ONTARIO	EASTERN ONTARIO
DEVONIAN	U	Port Lambton Gp. Kettle Point Fm.				
	M	Hamilton Gp. Marcellus Fm. Dundee Fm.	Dundee Fm. Lucas Fm. Onondaga Fm.			
	L	Detroit River Gp. Bois Blanc Fm.	Bois Blanc Fm. Oriskany Fm.			
		Bas Islands Fm.	Bertie Fm.			
		Salina Fm.	Salina Fm.			
SILURIAN	U					
	M		Guelph Fm. Lockport Fm. Clinton Gp. Cataract Gp.	Guelph Fm. * Lockport/Amabel Fm. Clinton Gp. Cataract Gp.		
	L		Queenston Fm.	Queenston Fm. *	Queenston Fm.	Queenston Fm.
				Georgian Bay Fm. Blue Mountain Fm. Collingwood Mbr.	Georgian Bay Fm. Blue Mountain Fm. Collingwood Mbr.	Georgian Bay Fm. Billings Fm. Eastview Mbr.
					Lindsay Fm. Verulam Fm. Bobcaygeon Fm. Gull River Fm. Shadow Lake Fm.	Lindsay Fm. Verulam Fm. Bobcaygeon Fm. Gull River Fm. Shadow Lake Fm.
ORDOVICIAN	U					
	M					
	L					
CAMBRIAN						



Units not present because of erosion
or non-deposition



Units in subsurface only

Gp. = Group, Fm. = Formation, Mbr. = Member

* Does not occur on Manitoulin Island

Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario
(adapted from: Bezys, R. K. and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario;
The Canadian Mining and Metallurgical Bulletin, v.81, no.912, p.49-58).

Appendix E — Aggregate Quality Testing

Six types of aggregate quality tests have been performed on selected samples from the project area. A description and the specification limits for each test are included in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the six tests listed in this appendix can be used to determine the suitability of an aggregate. The above six types of tests were performed by the Ontario Ministry of Transportation.

Absorption Capacity Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate. This test is conducted in conjunction with the determination of the sample's relative density.

Los Angeles Abrasion and Impact Test This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium Sulphate Soundness Test This test is designed to simulate the action of freezing and thawing on aggregate. Those aggregates which are susceptible will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Micro-Deval Abrasion Test The Micro-Deval Abrasion test is an accurate measure of the amount of hard, durable materials in sand-sized particles. This is a new abrasion loss test that is quick, cheap and more precise than the fine aggregate Magnesium Sulphate Soundness test which suffers from a wide multilaboratory variation. The maximum loss for HL 1/HL 3 is 20%, for HL 2 and HL 4/HL 8 it is 25% and for structural and pavement concrete it is 20%. It is anticipated that this test will replace the fine aggregate Magnesium Sulphate Soundness test.

Mortar Bar Accelerated Expansion Test This is a new rapid test for detecting alkali-silica reactive aggregates. It involves the crushing of the aggregate and the creation of standard mortar bars. For coarse and fine aggregates, suggested expansion limits of 0.10% to 0.15% are indicated for innocuous aggregates, greater than 0.10% but less than 0.20% indicates that it is unknown whether a potentially deleterious reaction will occur, and greater than 0.20% indicates that the aggregate is probably reactive and should not be used for Portland cement concrete. If the expansion limit exceeds 0.10% for coarse and fine aggregates, it is recommended that supplementary information be developed to confirm that the expansion is actually because of alkali-reactivity. If confirmed deleteriously reactive, the material should not be used for Portland cement concrete unless corrective measures are undertaken such as the use of low or reduced alkali cement.

Petrographic Examination Individual aggregate particles in a sample are divided into categories good, fair, poor and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

TABLE E1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

TYPE OF MATERIAL	COARSE AGGREGATE					FINE AGGREGATE			
	Petrographic Number Maximum	Magnesium Sulphate Soundness Maximum % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Mortar Bar Accelerated Expansion %	Magnesium Sulphate Soundness Maximum % Loss	Micro-Deval Abrasion % Loss		
Granular A	200	-	-	60	-	-	-		
Granular B Type I	250*	-	-	-	-	-	-		
Granular M	200	-	-	60	-	-	-		
Select Subgrade Material	250	-	-	-	-	-	-		
Surface Treatment Class 1	135	12	1.75	35	-	-	-		
Surface Treatment Class 2	160	15	-	35	-	-	-		
Surface Treatment Class 3	160	12	2.0	35	-	-	-		
Surface Treatment Class 4	-	-	-	-	-	20	-		
Surface Treatment Class 5	135	12	1.75	35	-	-	-		
Hot Mix - HL 1	100	5	1.0	15	-	16	20		
Hot Mix - HL 2	-	-	-	-	-	20	25		
Hot Mix - HL 3	135	12	1.75	35	-	16	20		
Hot Mix - HL 4	160	12	2.0	35	-	20	25		
Hot Mix - HL 8	160	15	2.0	35	-	20	25		
Structural Concrete, Sidewalk, Curb, Gutter and Base	140	12	2.0	50	**	16	20		
Pavement Concrete	125	12	2.0	35	-	16	20		

* requirement waived if the material has more than 80% passing the 4.75 mm sieve.

** Test results are analyzed for specific contracts. Please refer to Appendix E for detailed explanation.

(Ontario Provincial Standard Specifications OPSS 304, OPSS 1002, OPSS 1003 and OPSS 1010)



CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	Multiplied by	Gives	Imperial Unit	Multiplied by	Gives
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm ³	0.061 02	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.308 0	cubic yards	1 cubic yard	0.764 555	m ³
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 908 8	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

**MAPS
NOT
FILMED**

**CARTES
OMISES**